DISPOSITION FORM

For use of this form, see AR 340-15, the proponent agency is TAGCEN.

REFERENCE OR OFFICE SYMBOL	SUBJECT
ISCM	Classification Review - Operation Greenhouse Report

TO PAO FROM OAIS DATE 15 May 1979 CMT 1

A. Froling/jch/57559

1. Reference is made to your request regarding the declassification of WT-89 "Scientific Director's Report, Annex 9.3, Radiological Safety."

2. Cited report was declassified on 17 September 1974 and so noted in TID 1400 S2 "Status of Nuclear Test Reports."

3. The declassification action referenced in paragraph 2 above was ascertained in conversation between A. Froling, this Agency (ISCM) and Mr. I. Cucchiara, DOE on 14 May 1979.

4. Mr. Cuccniara further advised that the TID 1400 S2 is in "a state of revision" and that a copy was not available for our use.

5. Based on paragraph 2 above, this DF is the authority to declassify WT-89.

RB Sharkey S/

LOUIS OKYEN
Colonel, USA
Director for Intel & Scty

CY FURN:
Mr. Cucchiara

DA FORM 1 FEB 62 2496 REPLACES DD FORM 96, WHICH IS OBSOLETE.

PHOTOGRAPH THIS SHEET

ADA080271

DTIC ACCESSION NUMBER

II

LEVEL

INVENTORY

AEC

WT-89

DOCUMENT IDENTIFICATION

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

DISTRIBUTION STATEMENT

ACCESSION FOR		
NTIS	GRA&I	☒
DTIC	TAB	☐
UNANNOUNCED		☐
JUSTIFICATION		
Per Ltr. on File		
BY		
DISTRIBUTION /		
AVAILABILITY CODES		
DIST	AVAIL AND/OR SPECIAL	
A		

DISTRIBUTION STAMP

DDC
RECEIVED
FEB 11 1980
D

DATE ACCESSIONED

80 2 6 048

DATE RECEIVED IN DTIC

PHOTOGRAPH THIS SHEET AND RETURN TO DTIC-DDA-2

DTIC FORM OCT 79 70A

DOCUMENT PROCESSING SHEET

UNCLASSIFIED

[redacted]

WT-89

This document consists of 82 plus 4 pages
(counting preliminary pages)

No. 1 of 150 copies, Series A

Scientific Director's Report of Atomic Weapon Tests at Eniwetok, 1951

Annex 9.3

Radiological Safety

[redacted]

~~This document contains restricted data as defined in the Atomic Energy Act of 1946. Its transmittal or the disclosure of its contents in any manner to an unauthorized person is prohibited.~~

UNCLASSIFIED

[redacted]

[redacted]

Distribution

DEPARTMENT OF DEFENSE

	Copy
Armed Forces Special Weapons Project (Sandia)	1 – 3
Armed Forces Special Weapons Project (Washington)	4 – 15

ARMY

Army Field Forces	16
Assistant Chief of Staff, G-3	17
Assistant Chief of Staff, G-4	18 – 19
Chief Chemical Officer	20 – 23
Chief Signal Officer	24 – 27
Chief of Engineers	28 – 33
Chief of Ordnance	34 – 35
Operations Research Office (Johns Hopkins University)	36 – 37
Quartermaster General	38 – 42
Surgeon General	43 – 44

NAVY

Bureau of Medicine and Surgery	45
Bureau of Ships	46 – 47
Bureau of Supplies and Accounts	48
Chief of Naval Operations	49 – 50
Commandant, Marine Corps	51
Naval Radiological Defense Laboratory	52 – 54

AIR FORCE

	Copy
Air Force Cambridge Research Center	55
Air Research and Development Command	56 – 59
Air Targets Division, Directorate of Intelligence (Phys. Vul. Branch)	60 – 61
Assistant for Atomic Energy	62 – 63
Assistant for Development Planning	64
Assistant for Materiel Program Control	65
Deputy Chief of Staff for Development (AFDRD)	66
Director of Operations (Operations Analysis Division)	67
Director of Plans (AFOPD-P1)	68
Director of Requirements	69 – 70
Director of Research and Development	71 – 72
Eglin Air Force Base, Air Proving Ground	73
Ent Air Force Base, Air Defense Command	74 – 75
Kirtland Air Force Base, Special Weapons Center	76 – 78
Langley Air Force Base, Tactical Air Command	79 – 80
Maxwell Air Force Base, Air University	81 – 82
Offutt Air Force Base, Strategic Air Command	83 – 85
1009th Special Weapons Squadron	86
Rand Corporation	87 – 88
Scott Air Force Base, Air Training Command	89 – 90
Wright Air Development Center	91 – 93
Wright Air Materiel Command	94 – 95

ATOMIC ENERGY COMMISSION

Atomic Energy Commission, Washington	96 – 98
Los Alamos Scientific Laboratory, Report Library	99 – 103
Sandia Corporation	104 – 105
Technical Information Service, Oak Ridge (surplus)	106 – 148
University of California Radiation Laboratory (York)	149
Weapon Test Reports Group, TIS	150

[redacted]

[redacted]

RADIOLOGICAL SAFETY

by

JAMES P. COONEY
Brig Gen, MC, USA

Approved by

ALVIN C. GRAVES
Scientific Director

Washington, D. C.
July 1951

[redacted]

CONTENTS

CONTENTS (Continued)

ILLUSTRATIONS

ILLUSTRATIONS (Continued)

TABLES

Chapter 1

History

1.1 INTRODUCTION

In January 1949 Alvin C. Graves, Scientific Director, asked Brig Gen James P. Cooney (MC, USA) to command the radiological safety organization of the Scientific Task Group (TG 3.1) in proposed atomic weapon tests at Eniwetok. Gen Cooney was subsequently ordered to command Task Unit 3.1.5 (TU 3.1.5) and to act as Special Assistant for Radiological Safety on the staff of the Commander, Joint Task Force Three (CJTF-3).

The radiological safety policy and organization as planned for Operation Greenhouse were based to a large extent upon the experience gained at Alamogordo, Operation Crossroads, and Operation Sandstone. In the basic plan of organization the task force was divided into four task groups: Scientific (TG 3.1), Army (TG 3.2), Navy (TG 3.3), and Air Force (TG 3.4). Each was to have its own radiological safety organization, personnel, and instruments, and certain laboratory functions were to be supplied all task groups by TU 3.1.5.

The radiological problem divided itself into four phases:

a. Pretest phase — evaluation of the radiation hazards remaining on Operation Sandstone shot islands.
b. Planning phase — organizational planning of TU 3.1.5 for Operation Greenhouse.
c. Test phase — evaluation of and protection from radiation, blast, and thermal hazards during the detonation; evaluation of and protection from radiation hazards after detonation.
d. Final phase or résumé — evaluation of radiological safety operations during Operation Greenhouse.

1.2 PRETEST PHASE

Gen Cooney, assisted by Karl Z. Morgan, Oak Ridge, Carl C. Gamertsfelder, Hanford, Harry O. Whipple, Los Alamos, and Charles D. Blackwell, Los Alamos, made several trips to Eniwetok Atoll to supervise decontamination and preparation of the test islands for Operation Greenhouse. Permissible levels of radioactivity were exceeded in only limited areas of some Greenhouse test islands. These areas were those surrounding tower sites for Operation Sandstone tests.

It was considered advisable to avoid any possible overexposure to radiation, and therefore work was performed to decontaminate the areas where the radiation level was greater than tolerance. Decontamination was effected by bulldozing the top (heaviest contaminated) layer of earth into the crater and covering it with uncontaminated soil. Hazards from radioactive dusts were avoided by wetting the soil thoroughly before bulldozing. After the decontamination activities, Thomas N. White, Los Alamos, made the final survey of the entire Atoll during the period 5 to 11 May 1950. He concluded that there was no possibility of overexposure to gamma radiation on any of the islands of Eniwetok Atoll and that this condition would hold true up to the time of the next tests on the atoll islands.

It was decided, therefore, to discontinue the use of film badges on all islands and to terminate the full-time position of radiological safety

representative of the Los Alamos Scientific Laboratory.

1.3 PLANNING AND TRAINING PHASE

Operations plans for TU 3.1.5 were prepared and submitted to TG 3.1 as required.

Experience gained from Operations Crossroads and Sandstone clearly indicated that a closer relationship between the radiological safety unit and the scientific group was necessary. During Crossroads and Sandstone the radiological monitors were assigned to the various scientific groups only a few days before the tests, and in many instances met the scientists for the first time while on the way to the actual operation. In most cases the monitor had not been briefed on the scientific problem. His job was merely that of a meter reader. Alvin C. Graves and Gen Cooney decided that a much better integrated program between the groups was necessary. They felt that the monitor should be well acquainted with all phases of the project which he was to monitor. He should know what information the scientists were trying to obtain, the method used in obtaining it, and, most of all, how he could be of most assistance in helping the scientists obtain this information by solving the problem of radiological hazards. It was decided, therefore, that a special conference for the radiological monitors would be held at Los Alamos 1 to 6 October 1950.

Thomas N. White, Lt Col James T. Brennan, Maj Payne S. Harris, and Lt Col Leonard A. Eddy of Los Alamos arranged an excellent program in which every project director or his representative presented his program in minute detail to the entire group of monitors. These discussions covered:

a. The nature of the project—what information was to be obtained.
b. Pretest phase—what equipment was to be used, where and when it was to be placed, and an evaluation of the hazard in retrieving the equipment after the shots.
c. Operational plan—when it was necessary to obtain the data and the plan for doing so.

After the entire program had been discussed, the monitors were asked to state a preference for the projects on which they would like to work. In most instances it was possible to make the assignments requested. The monitors then spent a day with the project directors discussing details of their respective operations.

As a result of the information gained from this meeting an operations plan for TU 3.1.5 was outlined. Each monitor was given a specific assignment and remained with the same project throughout all tests, when this was possible.

It was felt that this meeting was extremely profitable to all concerned. In addition to the scientific projects, various administrative details were discussed. These included dates of departure for Eniwetok, duration of tests, mode of travel, physical examinations, payment of personnel, etc.

As a result of this meeting the radiological safety group was much better prepared to accomplish its mission.

Operational planning continued in the United States until the departure of the first large group of personnel about 8 February 1951.

1.4 PERSONNEL PROCUREMENT

At conferences in Washington 9 and 10 November 1949, attended by representatives of the Joint Technical Planning Committee (JTPC), J-Division of the Los Alamos Scientific Laboratory (LASL), Armed Forces Special Weapons Project (AFSWP), and the Services, it was decided that JTPC would coordinate procurement of military personnel required by J-Division and its various agencies. Accordingly, Alvin C. Graves, leader of J-Division, appointed Lt Col Donald G. Williams to be his executive for military personnel and asked, through him, that Gen Cooney state his military personnel requirements.

Gen Cooney established the requirement for 50 personnel: 30 officer monitors and 20 logistics and laboratory personnel. He canvassed personnel of sufficient experience and background and submitted the names of those who might be available. CTG 3.1 requested CJTF-3 to procure the personnel, some by name and some by job description only, from the Services on a temporary duty or temporary additional duty status during the operational phase. One civilian, Carl H. Menzer, was to be requested through civilian channels. It was also agreed

that nine civilian monitors from LASL would be assigned to TU 3.1.5.

When the conference of monitors was held at LASL in October 1950, it was for the first time possible to analyze the operations plans of the various scientific programs to determine the number of monitors required. It became evident that the 30 officer monitors and 9 civilian monitors would not be adequate, and requirements were established and approved by CJTF-3 for eleven more officer monitors. In a few cases personnel who had been requested were found to be unavailable and were replaced.

1.5 EQUIPMENT AND LOGISTICS

LCDR Donald C. Campbell, AFSWP, Howard L. Andrews, U. S. Public Health Service, and Gen Cooney held a conference at Los Alamos with Harry S. Allen and staff concerning the procurement and handling of all supplies required for the mission of TU 3.1.5. It was agreed that procurement of all equipment and supplies would be handled by Allen's group. His group would also package, mark, and ship equipment to Parry Island, where it would be delivered to TU 3.1.5.

All radiological safety equipment which had been stored at Los Alamos after Operation Sandstone was checked for serviceability. A complete list of additional items needed was submitted. LCDR Campbell and Andrews rendered technical advice and such other services as were required by Allen's group regarding procurement of equipment.

Chapter 2

Operations

2.1 INTRODUCTION

Additions to and deletions from the personnel roster continued until about 20 February 1951. Considerable difficulty in clearing personnel was encountered because such additions to the roster occurred. In approximately twelve cases, requests for Q clearance did not reach the FBI until about 12 January 1951, and as of 6 April 1951 (D−2 days) seven enlisted men of TU 3.1.5 remained uncleared. It was only by changes in JTF-3 orders on or about 20 March 1951 that uncleared personnel who had been certified by their commanding officers as good security risks were permitted to remain on Parry Island and continued use of their services could be planned by CTU 3.1.5. For future operations it is desirable that five or six months be allowed for obtaining Q clearances. One person of TU 3.1.5 was cleared in exactly three months after the request for clearance reached the FBI. All others required considerably more time. It is immaterial whether the delay in granting clearances is due to time needed for the FBI investigation or to time needed for processing within the AEC.

Movement of supplies and equipment to the Forward Area continued. In general, the supply and equipment situation was excellent throughout Operation Greenhouse. The only major items of equipment with which difficulty was experienced were the AN/PDR-T1B Radiac training set and Mine Safety Appliance Co. dust collectors. Eighty-five of the Radiac training sets were ordered and scheduled for delivery in the Forward Area on 1 February 1951. A change in the original order specified that the instruments were to be equipped with batteries and that 100 per cent replacement for batteries would also be furnished. On 31 March 1951, 60 of the AN/PDR-T1B's were delivered without batteries. Batteries for 10 AN/PDR-T1B's were obtained, and the instruments were used during Dog shot operations. The remainder of the instruments and sufficient batteries for all 85 AN/PDR-T1B's arrived shortly after Dog shot and were available for the remainder of Greenhouse. The Mine Safety Appliance Co. dust collectors did not arrive until shortly before the last shot and were of little use.

Movement of personnel to the Forward Area began on 14 February 1951 with the departure of the USNS General Aultman from San Francisco. The Aultman carried 27 officer monitors and TU 3.1.5 staff and reached Eniwetok on 27 February 1951. Gen Cooney arrived by air on the same date and on-the-site organization, training, and operation of TU 3.1.5 began. The next major movement of personnel, including most of the enlisted men, arrived on the USS Curtiss on 8 March 1951. Small groups and individual members of TU 3.1.5 continued to arrive until about 28 March 1951, when the roster of TU 3.1.5 could be considered essentially complete.

The staff of TU 3.1.5 was organized as follows:

Commander	Brig Gen James P. Cooney, MC, USA
Executive Officer	Lt Col James B. Chubbuck, CE
Technical Deputy	Dr. Thomas N. White, LASL
Laboratory Director	Dr. Howard L. Andrews, USPHS

Liaison with TG 3.2	1st Lt Thomas R. Ostrom, MSC
Liaison with TG 3.3	CAPT Harry H. Haight, MC, USN
Liaison with TG 3.4	Lt Col Karl H. Houghton, MC, USAF
Operations Officers	Maj Gerald M. McDonnel, MC, USA
	Lt Col Leonard A. Eddy, USAF
	Maj Payne S. Harris, MC, USA
Supply Officer	Maj Carl C. Carson, Inf, USA
Radiation Dosage Records	Lt Col John J. Maloney, MC, USA
Communications and Instruments	Prof Carl H. Menzer, University of Iowa

Monitoring for exposure to tritium was carried out under supervision of Dean D. Meyer, LASL. An account of this work is given in Greenhouse Report, Annex 1.10.

TU 3.1.5 headquarters was located in an aluminum building, the interior layout of which had been checked and approved by Gen Cooney. The building, although adequate, was not so large as would have been desirable. Office space, in particular, was cramped. Fortunately, the Officers' Beach Club was located very near TU 3.1.5 headquarters and was available for group meetings. It was found necessary to have rather frequent group meetings of the monitors, and the design of future radiological safety buildings should make provisions for space in which such meetings can be held.

Training of monitors began shortly after their arrival in the Forward Area. Instrument calibration began at once, and familiarization with radiation detection instruments was made an important part of the training program. Monitors were assigned to the various projects on about 10 March 1951 and began work with project directors. The assignment of monitors to projects well in advance of the shot date was an innovation and had not been done at previous weapon tests. This plan was a definite improvement over previous methods of operation since the monitors were fully familiar with their projects and with the personnel with whom they were to work prior to shot time. Weekly meetings were held on Saturday mornings for purposes of critique, orientation, and education. Talks at these meetings were given by outstanding scientists of TG 3.1, members of the TU 3.1.5 staff, and Gen Cooney.

2.2 DOG SHOT

The winds and weather prediction for Dog shot indicated that ideal conditions would prevail. From the surface up to 20,000 ft the winds were from the east and east-northeast with velocities all above 15 knots. Above this level the winds shifted gradually from the north to the west. On the basis of Sandstone data no fall-out problem could be foreseen and CTU 3.1.5 so advised CJTF-3. Winds and weather at zero hour were as predicted.

About 1 hr 40 min after the shot, the recording instruments in the radiological safety center indicated that a radioactive fall-out was occurring. The program director of TU 3.1.1 was notified and asked to notify all project directors of his unit to take measures to protect photographic films.

The occurrence of fall-out at such a short time after zero hour was a cause of considerable concern from a health standpoint. The problem presented two aspects, the external and internal hazards to personnel. The intensity, as it increased, was constantly checked both in- and out-of-doors. The radiochemical section of TU 3.1.5 began a study of the particle size. For more detailed information concerning the fall-out and particle sizes involved, see Sec. 2.6.

At about 1400 of D-day the intensity began to decrease, and it became obvious that external radiation accumulated by personnel would not be large. More detailed information concerning radiation dosages appears in Secs. 2.6 and 2.7.

It is a well-established fact that particles must be 5 microns or smaller in size to constitute an internal hazard. All data and facts at hand indicate that no particles smaller than 20 microns in size were present on populated islands. Therefore it is assumed that no internal hazards were present.

A total of 125 urine samples were analyzed. Three samples showed somewhat high counts on the first specimens, but a second sample on each individual, collected under supervision, was normal.

TU 3.1.5 encountered no other radiological problems in the test program. Excellent co-

operation was given by all scientific groups, and all work could have been done under normal conditions with no exposures exceeding 300 mr. The integration of the monitors with their respective programs proved very effective. Sufficient supplies and instruments were available except for one item, the air filtering devices. These dust collectors were ordered more than nine months in advance from the Mine Safety Appliance Co. Numerous follow-ups were made on this order, and delivery was repeatedly assured. Had this equipment been present, the investigation of the fall-out would have been facilitated.

Results of island surveys following Dog shot appear in Appendix A, and results of atoll surveys are given in Table 2.1.

Runit. At H+5 hr, fall-out was detected 10 to 15 miles east of Engebi.

The various cables on Engebi had been covered by huge piles of loose sand, extending across the island in various directions. Tons of this material were picked up and spread by the lower winds from Piiraai to Bogallua. However, it was possible to complete all scheduled E-day work with no excessive exposure.

During the night of E-day and the early morning of E+1, a fall-out occurred on Eniwetok, Parry, and Japtan. This was insignificant, amounting only to 2 or 3 times the background.

Work progressed satisfactorily on Engebi. Holmes and Narver performed excellent service in wetting down the roads and working

TABLE 2.1 ATOLL SURVEYS, DOG

	Intensity (mr/hr)					
	1500 8 April D-day	1000 9 April D+1	1000 10 April D+2	0830 11 April D+3	12 April D+4	13 April D+5
Eniwetok	25	7		2	2	1
Parry	60	15		6	5	3
Japtan	70	12		6	5	3
Aniyaanii	50	15	5	3	2	1
Biijiri	1	0.5	1.0	0.05	0.03	0.03
Engebi	2	0.2	0.1	0.1	0.03	0.03
Bogallua	1	0.4	0.03	0.03	0.03	0.03
Rigili	400	180	80	45	30	24
Giriinien	500	160	48	29	18	12
Ribaion		120	38	25	14	12
Pokon		62	38	20	14	10
Mui	250	62	29	20	12	8
Igurin	150	40	12	7	9	5

2.3 EASY SHOT

The wind structure as predicted at H−30 hr appeared ideal. The hodograph prepared by the meteorological service predicted the fall-out of the 50- to 200-micron particles at a distance of some 35 miles southwest of Eniwetok. However, the wind pattern changed, and, at the weather briefing at midnight prior to the shot, the hodograph predicted an area of fall-out of these particles inside the lagoon in the vicinity of areas, materially reducing the hazard from dust. As a result, very little contamination of clothing occurred.

One group of three film badges from three sailors, all of the same boat crew, showed unexplained high exposures of 10 to 20 r gamma and 15 to 30 r beta, acquired between 21 and 23 April 1951. Another sailor, although a member of the same boat crew, wore no film badge. In view of the above findings, the subject men were required to have a complete radiological

physical examination, including fingerprints, chest X ray, complete blood count, erythrocyte sedimentation rate, and urinalysis in accordance with existing naval regulations. The findings of these examinations were to be recorded on Standard Form 88 and in the health records of the men involved. Complete blood counts and urinalyses were to be accomplished at weekly intervals and findings appropriately recorded. Follow-up physical examinations were to be conducted in accordance with naval regulations. The men were not permitted for the remainder of Operation Greenhouse to enter areas in which any radiological hazard existed.

It is strongly suspected that a deliberate attempt was made to obtain a high exposure on the subject film badges, probably by leaving them on the shot island in a contaminated area for a considerable period of time, although none of the subject men would admit this. Certainly no other boat crew members operating under almost identical conditions obtained exposure within an order of magnitude of that obtained by the subject men.

Additional study on the fall-out problem was done by Thomas N. White and Harry F. Schulte (see Sec. 2.6).

Results of island surveys following Easy shot appear in Appendix B, and results of atoll surveys are given in Table 2.2.

2.4 GEORGE SHOT

The radiological safety problem after George shot was much simpler than after Dog and Easy shots. The winds were ideal, being from the west-southwest throughout their entire structure, thus eliminating the immediate downwind fall-out hazard in the Atoll. No secondary fall-out was detected on the Atoll from George shot.

A new procedure was initiated on this shot in that recovery operations were delayed until a radiological safety survey of the shot island was conducted. This survey was started about $1\frac{1}{2}$ hr after the detonation, and at noon, $2\frac{1}{2}$ hr after the shot, a radiological safety clearance for proceeding with recovery operations was issued.

Recovery operations were practically complete on 19 May 1951, and no significant or excessive exposures had been reported. The average exposure for personnel of TU 3.1.5 was about 700 mr per shot.

Film badge data from 3,180 individuals as of 15 May showed an average radiation dose of 422 mr. If casual visitors were eliminated from the list, the average dose received by 2,236 persons was 600 mr. This does not include exposures from fall-out after Dog shot and the subsequent lighter fall-out from Easy shot. The cumulative dosage on Parry from fall-out as of 14 May 1951 was approximately 2,200 mr out-of-doors. For further information concerning fall-out, see Secs. 2.6 and 2.7.

A radiological survey made during the week of 7 to 14 May 1951 on Ujelang, Ponape, Bikini, Rongelap, Lae, Ujae, and Kwajalein showed no significant contamination. Water samples that were collected on these islands showed no significant activity.

Results of island surveys following George shot appear in Appendix C, and results of atoll surveys are given in Table 2.3.

2.5 ITEM SHOT

Item shot was fired at the usual predawn time. According to the latest meteorological reports, the winds were in a transition period, and it was evident that the probability of fall-out on Parry and Eniwetok was borderline.

It had been agreed that no recovery would be attempted until at least 3 hr following the shot, at which time a preliminary radiological survey would be made. However, owing to some changes made on the night before the test regarding air transportation, it became necessary to attempt an early recovery. Therefore, at H+30 min, Maj Gerald M. McDonnel, Dr. Howard L. Andrews, and Gen Cooney flew to Engebi by helicopter and landed near Building 69. Upon arrival, the radiation intensity was about 400 mr/hr outside Building 69. The building was opened, and radio and telephonic communications were established with the radiological safety building on Parry. Another radiological survey was then made around Building 69, and it was found that the intensity had risen to 1.2 r/hr. It was evident that a large-particle fall-out was in progress. As a matter of fact, the falling particles could be felt on the face and hands. Radio communication was established

TABLE 2.2 ATOLL SURVEYS, EASY

	Intensity (mr/hr)									
	0730 21 April E-day	0900 22 April E+1	0900 23 April E+2	24 April E+3	25 April E+4	26 April E+5	27 April E+6	30 April E+9	3 May E+12	5 May E+14
Eniwetok	0.5	0								
Parry	0.5	0	0.8	0.6	0.6					
Japtan	0.5	0								
Aniyaanii	0.5	1	1	0.6	0.5	0.5	0.5		0.1	0.3
Runit	0.03	4	2.8	1.6	1.1	0.5	0.5		0.2	0.6
Piiraai	1	29	15	7	3	1	2			0.8
Biijiri	0.05	40	20	12	7	5	4		1.2	1.2
Eberiru	0.05	60	30	15	12					
Bokon	2,000	80	40	25	17	10	12			2.7
Kirinian	1,000	50	28	14	10	6	7			1.7
Muzin	1,100	32	18	10	6	1	3			1.0
Bogon	1,100	38	18	10	6	0	4	4		1.0
Teiteir	3,200	100	50	28	16	9	10	5		2.7
Bogombogo	25,000		900	450	320	220	180	100		44
Bogallua	32,000	1,000	900	600	350	200	150		60	46
Rigili	1	0	1.6							1.0

TABLE 2.3 ATOLL SURVEYS, GEORGE

	Intensity (mr/hr)					
	1400 9 May G-day	1000 10 May G+1	11 May G+2	12 May G+3	15 May G+6	22 May G+13
Aniyaanii	0.2	0.2	0.2	0.2	0.2	0.2
Runit	0.2	0.2	0.2	0.2	0.2	0.2
Piiraai	0.03	0.3				0.4
Bokon	3.2	6				1.0
Engebi	0.4	0.4	0.3	0.3	0.4	0.4
Teiteir	2.4	10				1.0
Bogallua	30	30	29	28	26	14
Rigili	1.6	1.6				1.0
Giriinien	1.0	1.0				0.8
Igurin	0.4	0.2				0.3

with W. E. Ogle's neutron sample recovery party on board an AVR, and they were told to remain about one mile offshore. At approximately 0830 the intensity had increased to 2 r/hr outside Building 69. The intensity then began to decrease rapidly, and at about 0930 it had declined to 200 mr/hr.

Shortly after arrival on the island two dogs were seen wandering about in the vicinity of Ogle's winch. One of the dogs came to Building 69, and it was given food and water. It appeared to be in a good state of health.

Ogle's AVR landed about 0945, and the recovery began. The cable, as usual, was broken about 100 yd from the winch. Gen Cooney accompanied Frederick Reines and party up to the 600-yd station to remove the neutron samples. Later a caterpillar tractor pulled in the rest of the land cable. The water cable was also broken, and only a portion of the samples were recovered on the first day.

Recovery work progressed in an orderly manner, and all parties were off the island well before sundown. On I+1 the usual radiological safety survey was made, and further recovery work progressed. On I+2 days all scientific material was removed from the 200-yd collimator station without any undue overexposure. On I+3 days the remaining portion of the water cable was recovered which completed all the recovery work on Engebi.

At approximately H+3 hr 23 min the gamma ray recorder at the radiological safety building on Parry Island showed a sharp rise, followed by a drop to nearly the original reading. This "spike" was interpreted as the result of the passage of an active cloud from which little material fell out. Several other spikes, followed by a steady rise in activity due to fall-out, continued until about H+4 hr 45 min.

A telephone call was made at noon to Japtan, and it was learned that a lesser amount of fall-out had been detected there. A telephone call to Eniwetok established the fact that considerably more fall-out had occurred on Eniwetok than on Parry. Thomas N. White and Gen Cooney flew to Eniwetok and, accompanied by Maj Scott and Capt Tuuri, made a complete radiological survey of the island. The intensity at that time was from 50 to 100 mr/hr on the upper end of the airstrip and approximately one half this amount in the vicinity of the bathing beach and the tent area. White and Gen Cooney returned to Parry Island and at about 1600 noted an increase in gamma ray intensity. This fall-out continued until about 1830. From H+16 hr the activity behaved according to a $t^{-1.2}$ law. A continuous record of gamma ray intensities was maintained. The integrated dose out-of-doors was determined by numerical integration of the intensity curve in the early phases and from direct dose measurements in the later phases. Telephonic communications with the USS Curtiss established the fact that fall-out of approximately the same intensity was occurring on the ship. A survey made on the northern end of Parry Island at approximately 1800 established the fact that the intensity there was less by

about 50 per cent than that on the southern end of the island and was approximately the same as the fall-out on Japtan. It became evident that the major portion of the fall-out occurred on the western part of the Atoll, decreasing at Eniwetok and Parry and decreasing further on Japtan.

Assuming that the decay continued according to a $t^{-1.2}$ law, it was possible to predict that if an individual had remained in the open for a period of 15 days the total dose received would have been 7,370 mr; at the end of 30 days it would have amounted to 9,520 mr. (Note: These predictions were not borne out by measurements made after the departure of the task force from the Atoll. Heavy rains set in at the end of May and apparently washed away most of the radioactive material from the inhabited islands.) The particles collected in a cascade impactor on Parry Island were all captured in the first stage of the instrument. Microscopic studies revealed them to be approximately the same size as those that fell during the Dog shot.

Results of island surveys following Item shot appear in Appendix D, and results of atoll surveys are given in Table 2.4.

2.6 FALL-OUT

2.6.1 Introduction

This section deals with investigations that were started a few hours after Dog shot when fall-out of radioactive material occurred on Parry, neighboring islands, and vessels. The fall-out was sufficient to give a gamma ray dosage rate of about 60 mr/hr on Parry. It was soon apparent that the total gamma ray exposure from this source would have no serious effect on the population (Sec. 2.6.4). It was not immediately apparent whether inhalation of the fall-out material was a serious health hazard. The answer depended primarily on the particle size distribution of the fall-out material. If the active material was carried mainly on particles considerably less than 10 microns in diameter, much of the material might reach the alveoli of the lungs, from which it would not be eliminated readily, and the possibility of serious consequences could be envisioned. If, on the other hand, most of the activity was carried by particles much larger than 10 microns, the situation, although undesirable from a number of

TABLE 2.4 ATOLL SURVEYS, ITEM

	Intensity (mr/hr)				
	1030 25 May I-day	1000 26 May I+1	0900 27 May I+2	28 May I+3	29 May I+4
Eniwetok	45	40	28	30	
Parry	6	30	18	10	
Aniyaanii	0.5	15	8	5.5	3.1
Runit	1.2	5	2.4	1.6	1.5
Piiraai	0			1.2	
Biijiri	0.02	2.2	1.4	1.2	0.9
Bogon	420	55	25	14	
Teiteir	550	60	33	18	
Bogombogo	10,000	850	700	400	
Bogallua	9,000	900	800	300	270
Rigili	7,000	650	450	280	170
Giriinien	2,800	410	250	140	110
Pokon	1,600	270	160	60	
Igurin	1,400	155	90	50	30

viewpoints, could not be regarded as a serious health hazard.

The main body of Sec. 2.6 comprises a report on fall-out that was completed just before Item shot. Certain observations on particle size of Item shot fall-out were added to this report in Sec. 2.6.13. There was nothing in these observations to alter the earlier conclusions.

2.6.2 Summary Account

Before going into details, subsequent developments are summarized under the following three subheadings.

2.6.2.1 Immediate Action

Within a very short time, substantial evidence was brought forth that most of the activity was carried on large particles.

A study of the wind soundings in the neighborhood of the shot time showed no westerly components below 20,000 ft. It was known that the fall-out started about 2 hr after the shot. The rate of fall of the particles must therefore have exceeded 10,000 ft/hr, and, by using Stokes' law, the size was computed to be 100 microns or greater. Earth samples were collected from Parry and other islands of the Atoll; a considerable number of particles were isolated by nonselective methods; and the sizes were measured under a microscope. All particles were found to be large (details are given in Sec. 2.6.5). A record of the radiation intensity versus time was made. The general character of this record suggested the settling of a cloud of large particles rather than the blowing by of a cloud of small particles of which a small proportion would be expected to settle out.

2.6.2.2 Supporting Action

Interest in the Dog shot fall-out was naturally widespread, and investigations were made both inside and outside the original scope of the TG 3.1 program by many individuals and projects. The following summary is confined to those investigations that were made by or at the request of CTU 3.1.5. Subject investigations were motivated by three primary considerations. In the first place, it was obviously desirable to support physical observations and calculations by biological investigations. Second, it was clear that more data were needed on the fall-out phenomenon to facilitate decisions concerning the feasibility of tower shots at the Nevada Proving Grounds. In the third place, the conclusions outlined in Sec. 2.6.11 were not accepted as fully established by all interested parties. The third point was discussed at a meeting, held several days after Dog shot, at which all professionally interested individuals were invited to present their views. It appeared that, at the root of the skepticism expressed about the large-particle conclusion, there lay the fact that no such large active particles had been observed among those isolated from the cloud samples drawn from previous shots. Considerable emphasis was also given to certain differences between the physical and chemical properties of the particles isolated on Parry (Sec. 2.6.5) and the characteristics of particles isolated from previous cloud samples. The suggestion that such negative evidence was invalid, on account of the relatively small number of particles needed to account for Dog shot fall-out, was apparently too tenuous a counter-argument to be convincing.

Many other arguments were presented on both sides. It appeared desirable to seek, at subsequent shots, further evidence bearing on the presence or absence of heavy active particles in the cloud at high altitudes immediately after the shot. Direct cloud sampling with available equipment was inapplicable since it had provided no pertinent information in the past. It appeared that the best that could be done was to attempt to catch particles immediately before they reached the surface. It was planned to attempt to do this where fall-out similar to the Dog shot fall-out on Parry was expected to occur, as predicted by the meteorologists. Particles so caught could not be suspected of having become attached to larger particles after contact with the soil. The findings of fall-out in the predicted area would, it was hoped, give convincing verification of the meteorological data and methods of prediction.

2.6.2.3 Reconsideration of Past Information

It is frankly admitted that the Dog shot fall-out in the neighborhood of Parry came as a complete surprise, regarding both the early hour of arrival and the intensity of the radioactivity. It is necessary in assessing the state of current knowledge to inquire whether any earlier information had been neglected or mis-

interpreted. In the past, tests were conducted under somewhat similar conditions at Alamogordo and at Eniwetok.

About 4 hr after the Alamogordo test there appeared a "hot" region of about 15 r/hr at about 25 miles from ground zero. In the early discussions of the feasibility of the Nevada Proving Grounds, this phenomenon was attributed by some authorities to "rain-out." Although others who had been present at the test persistently questioned this explanation, the rain-out theory was accepted rather widely. A review of available information shows that the evidence against rain-out was in fact so strong as to be practically conclusive.

The Alamogordo bomb was detonated on a 100-ft tower over unstabilized soil. At Operation Sandstone, the bombs were detonated from 200-ft towers over a very different type of soil, stabilized to different degrees for the different shots. No comparable radioactive fall-out was observed. A review of the wind data shows that the regions where fall-out might have been expected lay outside the Atoll to the northward for each of the three shots. No surface observations were made in this region.

For a long time there has been available enough information on rate of rise of the fireball to calculate that large particles could be carried up to very great heights. This does not prove that any specified quantity of material is in fact carried up. Even if the calculation were quantitative in this respect, the degree of activity of the particles, which is just as important as the number and size, would be very uncertain. It is understood that large particles have been found in cloud samples, but not large radioactive particles. This absence of large radioactive particles was probably the strongest single factor in building up a false sense of security. That this negative evidence may be no better than the negative Sandstone evidence is indicated in Sec. 2.6.9.

It is quite possible, however, that there was no significant amount of radioactive dirt carried to high altitudes in Sandstone clouds. The heavy-particle fall-out observed at Greenhouse may be due to the presence of some new factor. It is possible that the materials and methods used for the stabilization of the soil around ground zero may have had a very large effect on the quantity of large radioactive particles which were airborne. If the large active particles are formed by the sticking of small active particles onto pieces of dirt, then it seems that some special condition or material is needed to facilitate this process, since the inactive large particles appear to be much more numerous.

Without more knowledge of the way in which the large active particles are formed, it appears to be very risky to use the Greenhouse fall-out to predict the intensity of fall-out under other conditions.

2.6.3 Surveys Subsequent to Dog Shot

The effort to obtain, from subsequent shots, data on fall-out comparable to that which had occurred on Parry after Dog shot was pushed along two lines. More equipment was put to work on selected islands of the Atoll, and provision was made for measurements out to sea. The scope of the effort along both lines was severely limited by many factors, including shortage of time, personnel, and logistic support.

Insofar as air sampling on atoll islands is concerned, no positive results were obtained. Locations had to be chosen and the equipment set up long before any reliable forecasts could be made. No significant fall-out occurred at the locations chosen. The regular atoll intensity survey showed that, after Easy shot, the heaviest fall-out from the upper air levels occurred in the vicinity of Kirinian. According to the wind soundings, this fall-out must have occurred from above 30,000 ft. Intensities were about 1,000 mr/hr at H+1 hr. The fall-out factors were similar to those of the Dog shot fall-out on Parry, and, although there were certain differences that would have made one expect a more intense fall-out, the fall-out was the same as that observed after Dog shot. As shown in Sec. 2.6.6, the fall-out observed from Runit to Bogallua was in good agreement with the wind soundings taken at about shot time, and many good island air sampling locations would have been available if they could have been set up a few hours before the shot. The particle size distribution at 40,000 ft, as calculated from the intensity survey, gave an average value of about 160 microns. Following George shot there was no significant fall-out on any of the islands of the Atoll.

For Easy shot the survey at sea took the form of a surface survey, with air sampling

equipment aboard the destroyer USS Walker, and an aerial survey by the AEC B-17 Yellow How, a stand-by drone manned for this mission. For George shot only the B-17 was used. In each case the B-17 carried the full complement of cloud sampling equipment except the snap sampler. On the first mission, because of some difficulties associated with the change from automatic to manual operation, all the equipment was not utilized to the fullest advantage. All the activity collected after Easy shot by the air sampling equipment on the destroyer was contained in three large particles (80, 100, and 200 microns in diameter). Details are given in Sec. 2.6.7.

With neither the destroyer nor the B-17 were intensities found comparable to those of Dog shot. The B-17 found an irregular distribution of low activity averaging about 2 mr/hr. The Project 1.7 (wing) filter contained many active particles, but only a few could be isolated on account of difficulties in extraction from the paper. Those isolated were 50 to 100 microns in size. Flight statistics are given in Sec. 2.6.8.

The results of the gamma intensity survey conducted for George shot were eminently satisfactory. Fall-out was detected at the predicted time and location. The time and intensities were nearly the same as those observed on Parry after Dog shot. The area of search was limited by rain squalls. There is no assurance, therefore, that the observed maximum of 150 mr/hr was the maximum existing in the vicinity. However, even a maximum as low as 150 mr/hr at 60 miles, $2\frac{1}{2}$ hr after the shot, has important implications. Both theory and observations indicate that intensities several times greater would exist at ground level after the material had settled on the ground. For Easy shot, the intensity observed on the deck of the destroyer was much greater than anything observed with the B-17.

In the cascade impactor on the B-17, almost all the activity was collected on the first stage. The active particles could not be isolated because of a prior agreement not to disturb the material before it was shipped back to the owners. However, the active region of the plate was localized, and it was observed under the microscope to be occupied mainly by a few particles of 50 to 100 microns in diameter.

2.6.4 Intensity of Radiation from Dog Shot Fall-out on Parry and Japtan

At 0850 D-day the background count, on recording rate meters operating with gamma ray counters in the radiological safety building, Parry Island, rose precipitously. These counters were set at a relatively high sensitivity and went off scale so that the first phase of the fall-out was lost, but the rate of rise was obviously very rapid. The recorders were brought on scale at 0915, and one was operated until the activity due to fall-out had dropped to a relatively low value. Fall-out continued until about 1400 D-day. Figure 2.1 shows the build-up of the fall-out.

At about 1000 a survey of Parry Island was made with an ionization chamber survey instrument. Although there were some small areas of relatively high activity (up to 1,000 mr/hr), the island as a whole showed a rather uniform level of contamination.

Decay curves indicated a possible component with a 7.7-hr half life followed by a decay following a $t^{-1.2}$ law (see Fig. 2.2).

The maximum intensity for Japtan was estimated from survey meter readings to be about 10 per cent greater than that on Parry Island. No comparable data are available from Eniwetok Island, but survey meter readings made early in the fall-out showed intensities about two thirds of those on Parry Island.

2.6.5 Particles from Dog Shot Fall-out on Atoll

The method of studying the particulate size of the fall-out on Dog shot, as finally decided upon by the radiological safety laboratory, was one of mechanical separation. Samples were collected from spots showing activity higher than the average of the surrounding area. The sample was then divided and subdivided many times until it was indicated by the use of a portable Geiger counter, beta window open, that one portion of the material contained more activity than the corresponding portion. Further division was required, following the activity closely, until the last separation was made onto a microscope slide by the aid of a 2-mil wire. Approximately one hundred such separations and isolations of active particles were made.

The size of the particles could only be estimated at first because no micrometer was

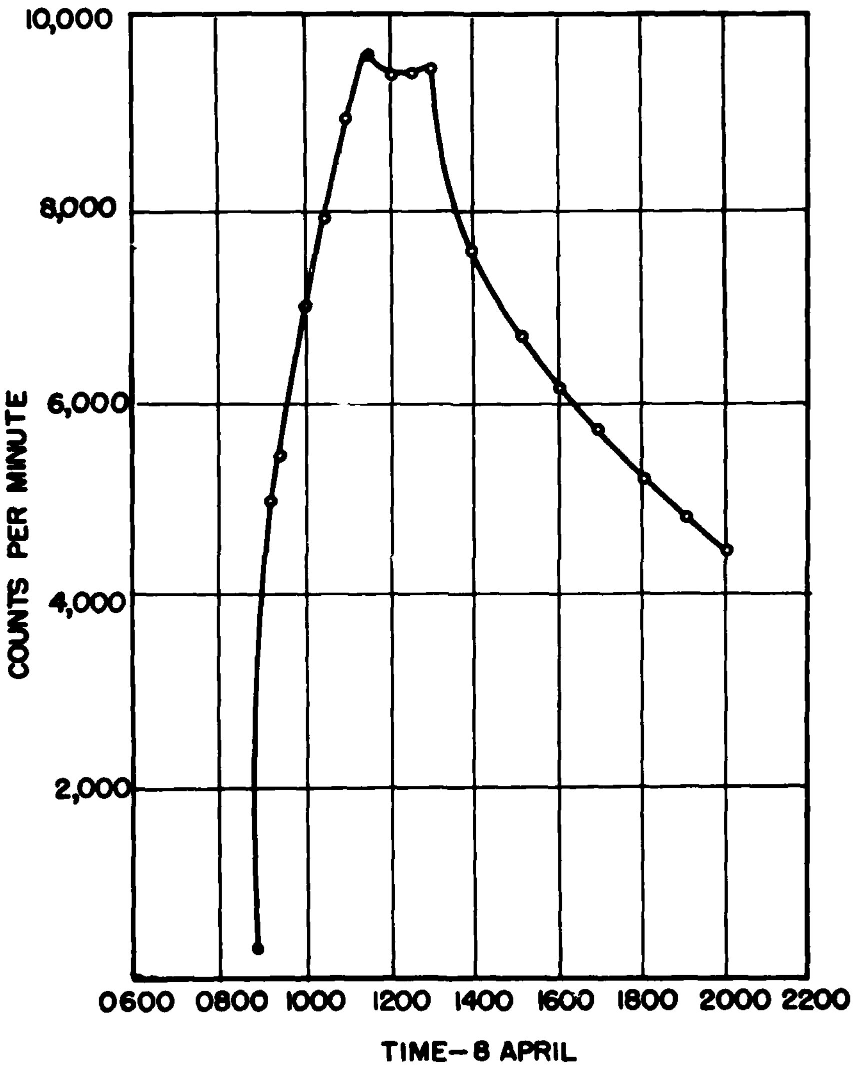

Fig. 2.1 Fall-out Activity, Parry, Dog Shot

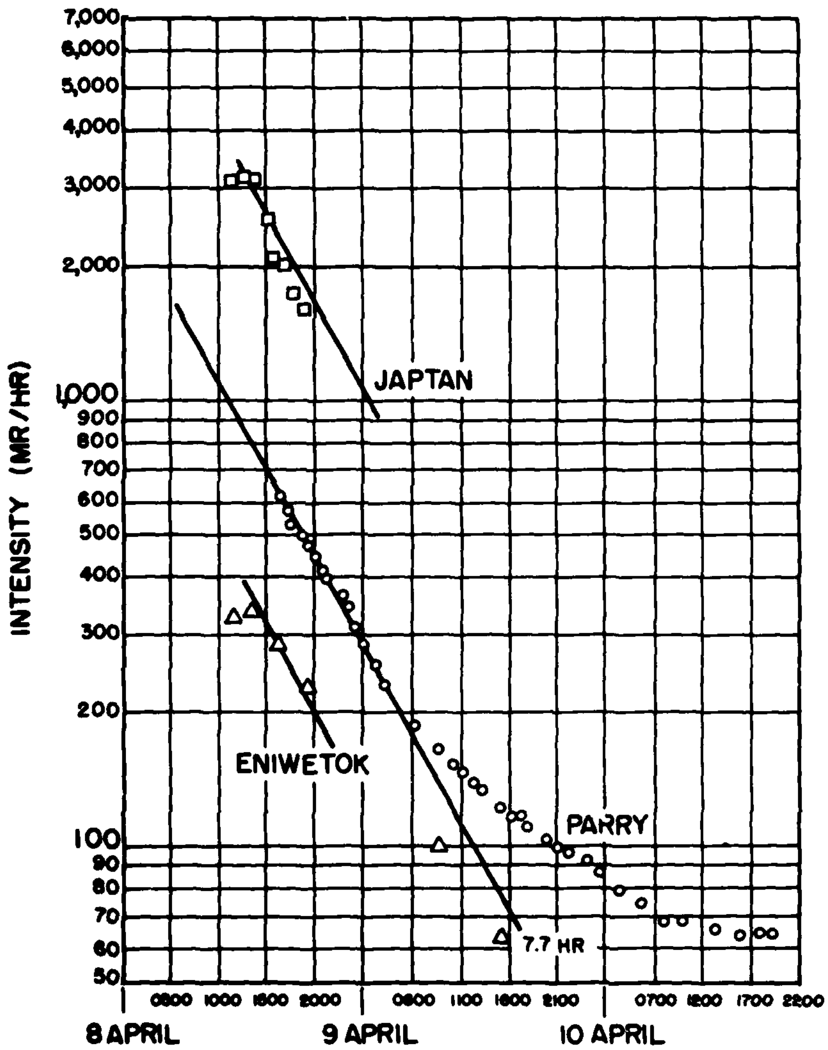

Fig. 2.2 Decay of Dog Shot Fall-out Gamma Activity

available. The low power lens system, 125 × magnification, was used. The estimation of the size was made by comparison with a red blood cell which is known to be 7 to 8 microns in size. Thus compared, the particles separated appeared to be 50 to 150 microns average diameter.

Some of the very largest particles found were from the island of Rigili. One of these measured between 1 and 2 mm. It was crushed between two microscope slides and divided into roughly three portions. Each portion carried part of the activity which indicated more or less thorough mixing when the particle was made.

The appearance of the average particle was that of a mixed amorphous substance. On the outer layer of most particles, there appeared to be black specks estimated at 5 microns or less. Some of the larger particles appeared to have a small tip on one edge with the tip containing the black material.

Attempts were made to identify one or more parts of the amorphous system. Dilute hydrochloric acid was dropped onto the slide and carefully added to the crystal. Bubbles could be seen through the microscope, and after the evolution of all the gas there remained quartz-like threads and black particles, neither of which could be visually characterized. The bubbles were assumed to be carbon dioxide from the reaction of the acid on coral sand. Upon one occasion, to assist in identification, a Kleenex was used to remove the excess acid, and a drop of water was added to wash off the slide. No activity was carried on the Kleenex. Careful division of the remaining residue was made, and activity was carried with each division. It was thought that the black part could be iron, but it did not appear to dissolve, even in 6N hydrochloric acid after several minutes. Ammonium thiocyanate solution was added, and no identification of iron could be made. No further chemistry was attempted.

When a micrometer scale became available, photomicrographs were made of about fifteen particles. The slides were then preserved with a piece of scotch tape. Samples that were collected and examined included those from islands of the Atoll from Parry around to Rigili.

Microscopic studies of mechanically separated particles, which included samples from seven southern islands of the Atoll, indicated that the fall-out of the first 6 hr after Dog shot was 20 to 250 microns. No particles smaller than that indicated were found, but a few larger ones were separated.

2.6.6 Intensity of Fall-out on Atoll, Easy Shot

The systematic periodic intensity surveys of the islands following Easy shot show a number of characteristic features that can be compared with fall-out predictions made from wind soundings.

Of the string of islands extending generally westward from Engebi, the heaviest fall-out (30 to 40 r/hr) occurred on the extreme western two, Bogallua and Bogombogo. These islands lie somewhat to the south of west, in the direction of the winds below 10,000 ft. Of the intermediate islands, those large enough to catch much fall-out lie somewhat to the north of west. These showed much less intensity (around 1 r/hr). Wind soundings showed that fall-out in this sector would be scattered on account of very variable winds in the range 20,000 to 25,000 ft.

Of the islands extending generally to the southeast of Engebi, the highest intensities (around 1 r/hr) were found on the closest, Muzin, Kirinian, and Bokon. Progressively lower intensities were observed on farther islands, with significant values (40 mr/hr) as far as Runit, at about 10 miles. According to the predictions, this fall-out should have come from the 40,000-ft region and should not have been completed at the time the first surveys were made. On Biijiri it was apparent that most of the fall-out occurred after about 3 hr. For a long time the high activity on Muzin, Kirinian, and Bokon was thought to have gotten there within 1 hr of shot time, when the first survey was made. This early time coupled with the lower activity (400 mr/hr) at the southeast corner of Engebi, which is much closer to ground zero, was difficult to understand. An attempt was made to account for it on the basis of blast wind phenomena. Subsequently, an analysis of the decay of island activities by Maj P. S. Harris, Assistant Radiological Safety Operations Officer (see Figs. 2.3 and 2.4) indicated that the fall-out on Muzin, Kirinian, and Bokon was not complete at the time supposed. It appears that the relatively low intensity at the

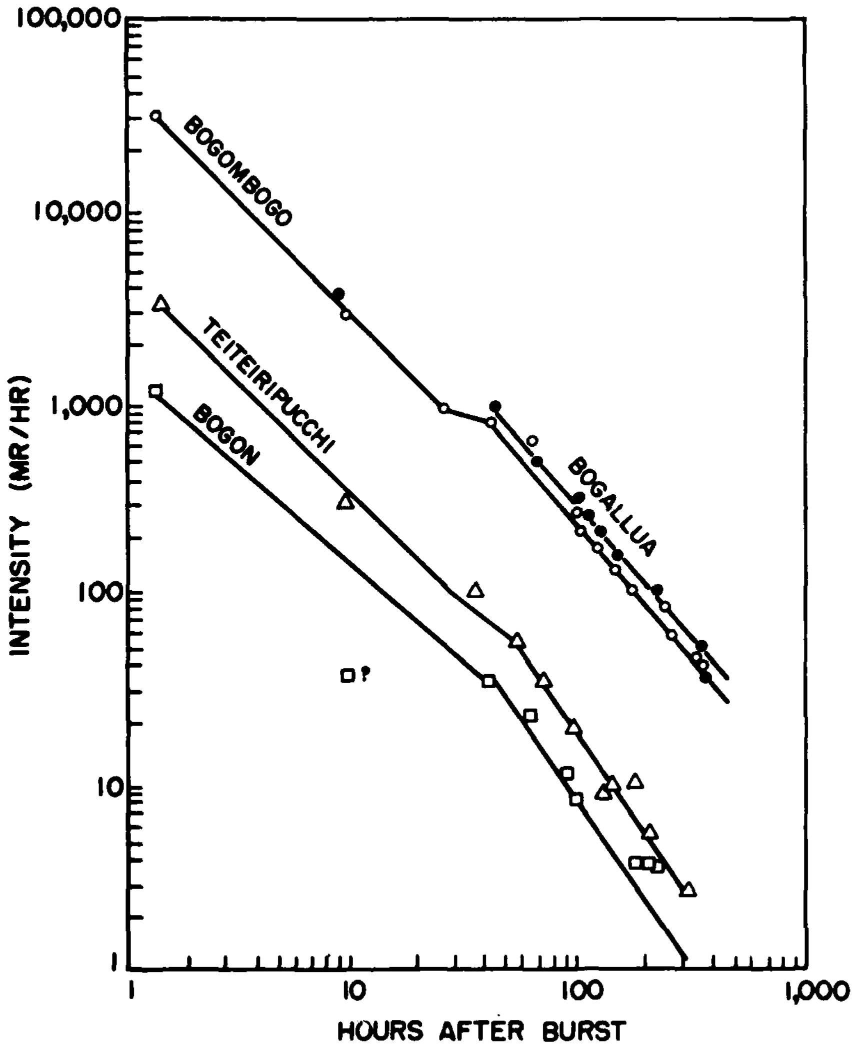

Fig. 2.3 Rise and Decline of Fall-out Activity on Several Atoll Islands West of Engebi, Easy Shot

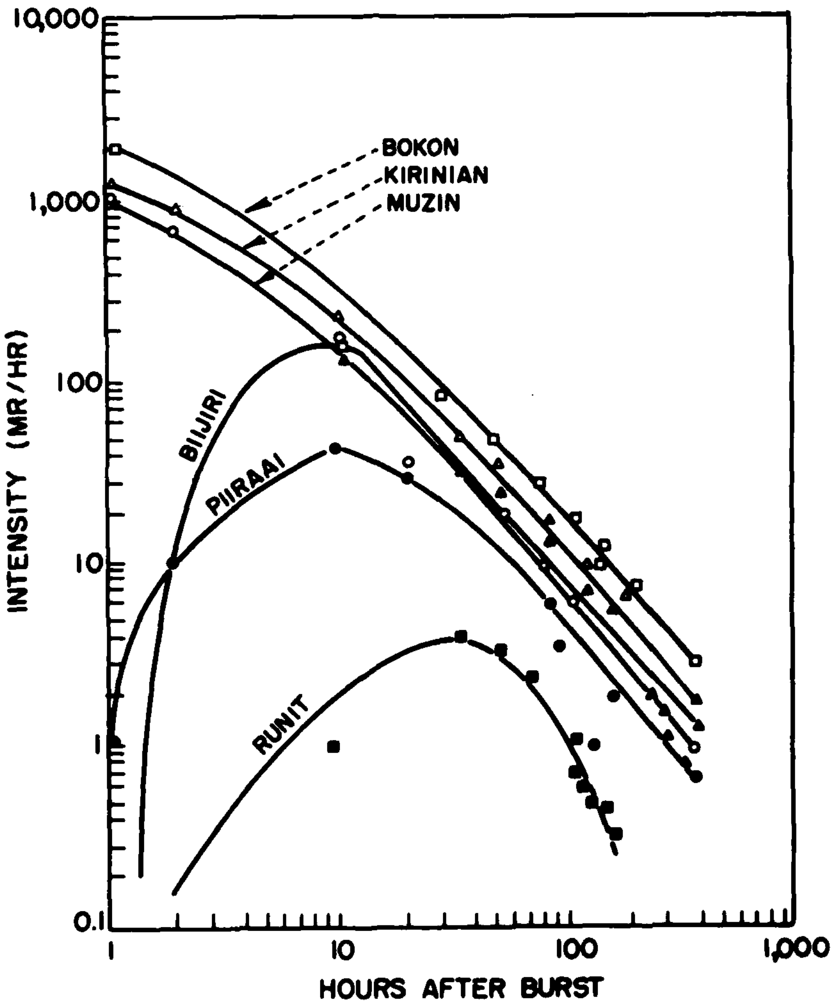

Fig. 2.4 Rise and Decline of Fall-out Activity on Several Atoll Islands East and Southeast of Engebi, Easy Shot

south end of Engebi can be explained fairly easily. It seems to be due to the upper size limit of particles at a given altitude.

Surveys were made daily to determine the decay of these areas of high intensity. Figure 2.3 includes the surveys of four islands west of Engebi. Figure 2.4 includes six islands east and southeast of Engebi. As can be seen from the curves, the results for neighboring islands agree well even though the readings were made hurriedly with a standard gamma ionization chamber. All readings were made approximately 1 meter off the surface of the ground. In no case can it be said that repeated readings were taken at exactly the same point.

On examination of Fig. 2.3 there are two definite slopes apparent. There is a break between 24 and 48 hr after burst. This break can probably be best explained by fall-out occurring during this time. This is reasonable in that continued background determinations made by TU 3.1.5 at the radiological safety laboratory on Parry indicate that fall-out occurred at this time. By examining the slopes of these various lines several interesting findings arise. It is found that, if $I = I_0 t^{-x}$, where I is intensity in mr/hr and t is time in hours after burst as determined graphically, the decay up to 24 hr after burst is proportional to $t^{-1.2}$. This agrees with fission product decay as originally determined by Way and Wigner. However after 48 hr the decay is proportional to $t^{-1.4}$ or $t^{-1.5}$. This is significantly different from what is usually expected for fission products. Why this should occur was unknown at the time of writing. Whether it is due to particle size, fission chemistry, etc., cannot be determined without more data. It is of interest that the change in slope did not become apparent until after the fall-out occurring between 24 and 48 hr after burst.

From Fig. 2.4 it is noted that fall-out was continuous from 1 hr to 10 to 20 hr after detonation. After these times recognizable decay occurred on the slopes shown in Fig. 2.2 which indicates that the decay is proportional to $t^{-1.4}$.

The six islands, Muzin, Kirinian, Bokon, Biijiri, Piiraai, and Runit, lie on about the same bearings (120 to 135 degrees) from ground zero and at distances from 1 mile to about 10 miles. Taking, from the wind soundings at shot time, the prediction that 75-micron particles, from about 40,000 ft above ground zero, would land at about 10 miles on this bearing, the vertical velocity of fall and the size of the particles for the different islands can be estimated. The velocity can be estimated in two ways. Particles landing at half the distance would have to fall at twice the speed of 75-micron particles. From the graph of island activity versus time, some estimates can be made of the time of arrival of one half of the particles, from which an estimate of the speed of descent from 40,000 ft can be calculated. For the three islands nearer Engebi, most of the fall-out had occurred before the first observations. However, with particles falling so fast, the 50 per cent point must have occurred only a little earlier. The fall-out times for the farther three islands are subject to considerable error, both because of the scarcity of points on the built-up portion of the curves and because of the shifting of winds during the intervening period. The latter factor also introduces uncertainty in the estimate of velocity from distance, because the predicted distance of 75-micron fall-out changed with time.

After deciding on compromise values for the rate of fall, the particle size can be estimated from Stokes' law (assuming the specific gravity of the particles to be 2). The relative amounts of different sized active particles originally in the cloud at 40,000 ft can then be estimated from the relative intensities on the islands at some time, for instance, H+100 hr, when fall-out was certainly complete. This estimate is probably much too low for the small particles on account of the shift in winds with time. The results are given in Table 2.5. When plotted they indicate a range from 60 microns to nearly 300 microns, with an average size of about 160 microns. Stokes' law, together with data on rate of rise of the fireball, gives an upper limit of about 170 microns for the size of particles at 40,000 ft. In view of many uncertainties in both calculations, the disagreement is not at all serious.

It is emphasized that, although this distribution of particle sizes may be erroneous with regard to the initial conditions in the cloud, the errors are not of immediate practical significance. It is the size distribution of the particles that reach the ground which is of importance to the people working there. There is no reason to suspect that the calculated distribution is seriously in error in this respect.

UNCLASSIFIED

[redacted]

TABLE 2.5 DISTRIBUTION OF ACTIVE PARTICLES

	Muzin	Kirinian	Bokon	Biijiri	Piiraai	Runit
Nautical miles from zero	1.1	1.6	2.8	6.0	7.2	10.5
Bearing (degrees)	135	130	125	120	125	130
Maximum mr/hr	1,000	1,100	2,000	180	40	4
H+hours at maximum	0.85	0.9	1.0	8	10	27
Hours to 50% fall-out	0.85 –	0.9 –	1 –	6	14	23
Velocity (1000 ft/hr):						
From distance	45	31	18	8	7	5
From time	47+	44+	40+	7	3	2
Compromise	47	40	30	8	5	3
Mr/hr at 100 hr	6.2	9.4	16	6.6	5.0	0.95
Particle diameter (microns)	240	210	180	95	75	60
Initial % in cloud	14	21	36	15	11	2

2.6.7 Air Sampling on Destroyer, Easy Day

In an attempt to secure further data on the nature of the fall-out material, a study was made on the USS Walker during the hours following Easy shot. Commencing at H-hour and during the next 12 hr, the ship pursued a course due east of Engebi, running from 10 miles east to 15 miles east and then returning on the same course.

On the night of E – 1 the background level on the deck was 0.1 mr/hr. This same level prevailed prior to the shot on E-day and until 1130 hr when it began to rise rapidly, reaching a maximum of 6 mr/hr 6½ hr after H-hour and then declining slowly.

Immediately after the shot, air sampling was begun by drawing air through a filter paper wrapped around a Geiger tube probe. This showed no increase in activity on the filter paper until the general rise in the background at 1130. Immediately after this the filter paper activity showed a rapid rise.

A cascade impactor sample (CI-1) was taken from 0950 until 1125. At 1225 a second cascade impactor sample (CI-2) was started and ran for 1 hr. At 1350 p.m., sampling was started with the molecular filter (MF-1), and this was run for 75 min. Since by this time the background was decreasing, no further samples were collected.

The air samples obtained were counted on E+1 day in the morning. No activity greater than background was found on any of the five stages of CI-1. In CI-2, taken during the background rise period, there was no activity appreciably above background on stages 3, 4, or 5. Stages 1 and 2, however, contained too much activity to count the first day. However, on E+2 day, counts of 35,800 c/m and 16,800 c/m were obtained on stages 1 and 2, respectively. The counter efficiency was approximately 7.6 per cent.

The molecular filter sample taken from 1350 to 1505 showed a level of activity on E+1 day which was not significantly greater than background.

Since essentially 100 per cent of the activity on CI-2 was located on the first two stages, a search was made for particles. Portions of the slides were blocked off by means of glass slides, and the activity was checked with a survey meter. On both slides the activity was found to be highly localized. The active areas were then searched under the microscope. On slide No. 1 two particles were found in the active area which were similar in appearance to those previously isolated from soil samples in fall-out areas after Dog shot. One such particle was found on slide No. 2. Removal of each of these particles by means of a needle point showed them to be highly active. Recounts of activity remaining on the slides showed that the levels had dropped to less than 1 per cent of the level obtained before removal of those three particles.

Size measurements with the eye-piece micrometer showed the active particles to be 200

[redacted]

UNCLASSIFIED

and 100 microns on the No. 1 slide and 80 microns on the No. 2 slide. Assuming the usual decay curve these particles must have had an activity of approximately 1 μc each. The volume of the air sampled was 1.05 cubic meters.

These particles were distinctive in shape and general surface appearance. Despite the presence of other dust particles on the impactor slides, the active particles could be immediately singled out on a basis of appearance alone once the general active area was located.

Since these particles were obtained from the air, the activity was already attached to the particle before it reached the ground. Since the size, shape, and appearance of these particles were similar to those previously isolated, this would seem to confirm the assumption that the previously isolated particles were airborne also.

2.6.8 Aerial Search for Heavy-particle Fall-out

On Easy day an aerial survey was conducted from H+3½ hr to H+5½ hr. The B-17 flew at 500 ft in an area 20 miles east-west by 15 miles north-south with the center of the area 10 miles east of Rojoa. Intensities observed were: minimum 0.7 mr/hr, maximum 5.0 mr/hr, and average 1.85 mr/hr. Within 2 miles of the destroyer Walker's course from H+3¾ hr to H+4 hr, intensities observed were: minimum 0.9 mr/hr, maximum 3.5 mr/hr, and average 1.85 mr/hr.

TABLE 2.6 NET COUNTS PER MINUTE WITH A COUNTING EFFICIENCY FOR UX_2 BETA OF 8.8 PER CENT

	H-hours			
Stage	6½	11½	24½	26
1	7,464*	8,538*	4,538*	4,305
2	642	353	228	150
3	196	107	54	63
4	42	17	39	15
5	52	42	72	19

*These counts were made before the active area of the slide had been localized and are very unreliable. The area of impaction was visible on the other slides, which could therefore be properly positioned under the counter window. Background counting rate, 37 c/m.

On George day an aerial survey was conducted from H+2 to H+3 hr. The B-17 flew at 500 ft in the area shown in Fig. 2.5. Intensities observed are shown in Figs. 2.5 and 2.6.

From the rather close agreement between the locations of the predicted and observed fall-out, the following rough estimates can be made concerning the altitude of origin of the fall-out, the particle size, and the relative amounts of active material. The two small peaks in the southeastern part of the area of search are excluded as too close to the border of the predicted fall-out to be reliable.

The counts obtained by the cascade impactor before the slides were returned to Project 6.1 for shipment to the Zone of Interior on G+1 day appear in Table 2.6.

2.6.9 Number of Active Heavy Particles Needed for Dog Shot Fall-out

Can large particles, of a kind needed to account for Dog shot fall-out on Parry, exist without having been observed in previous cloud-sample studies?

To abbreviate, in the ensuing calculations, OM means "of the order of magnitude of."

As one starting point in the discussion, it is taken that previous cloud-sample observations indicate a typical particle size, OM 5 microns, and that the characteristics of these particles are consistent with the assumption that they are produced by the scavenging of most of the fission atoms by OM 100 tons of vaporized tower and bomb material. Under these conditions, the number of small particles is OM 10^{18}.

The activity associated with particles of typical size, a few hours after shot time, is taken as OM 10^{15} μc/10^{18} particles, which equals 10^{-3} μc/particle.

As another starting point, it has been found that the observed variations in surface intensity cannot be accounted for if the surface concentration of Dog shot fall-out particles on Parry and neighboring islands was substantially in excess of 1 particle/sq cm, or 1,000 particles/sq ft, or OM 10^{10} particles/sq mi. Also the intensity observed on Parry following Dog shot was such as to require a surface activity OM 10^{10} μc/sq mi, or 1 μc/particle/sq cm (observed activities of isolated particles agreed with this value).

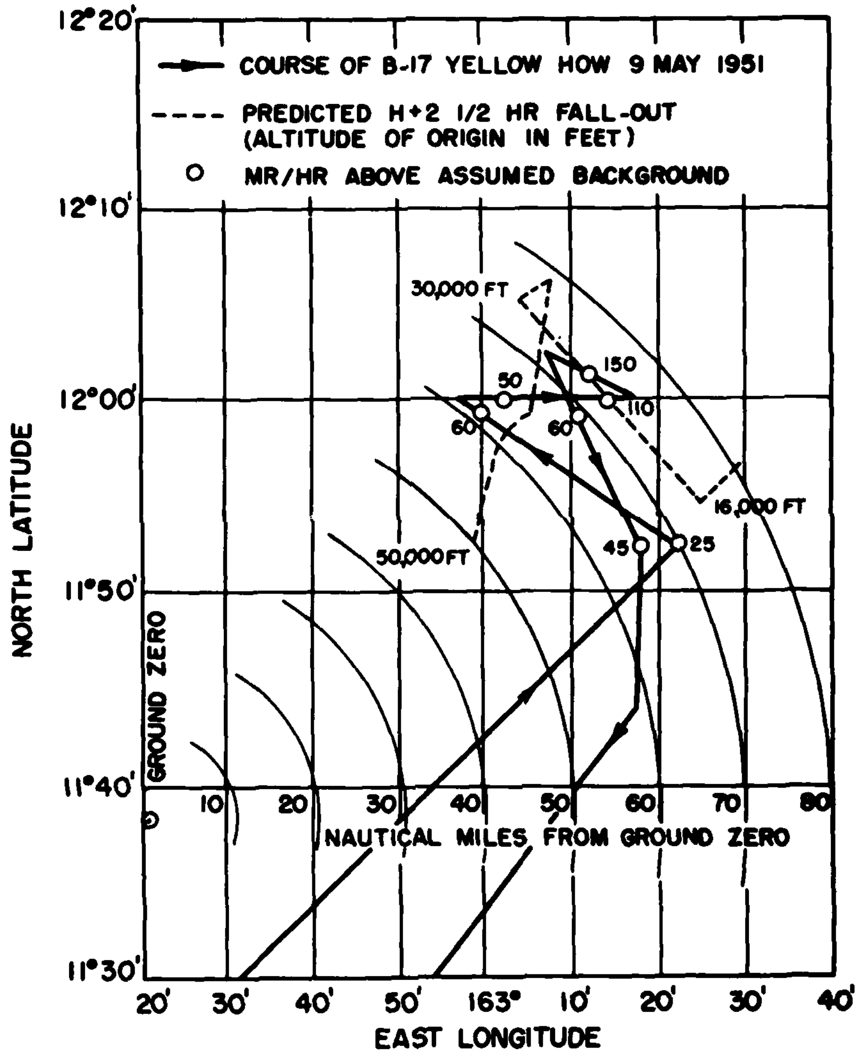

Fig. 2.5 Course of B-17 Yellow How, 9 May 1951

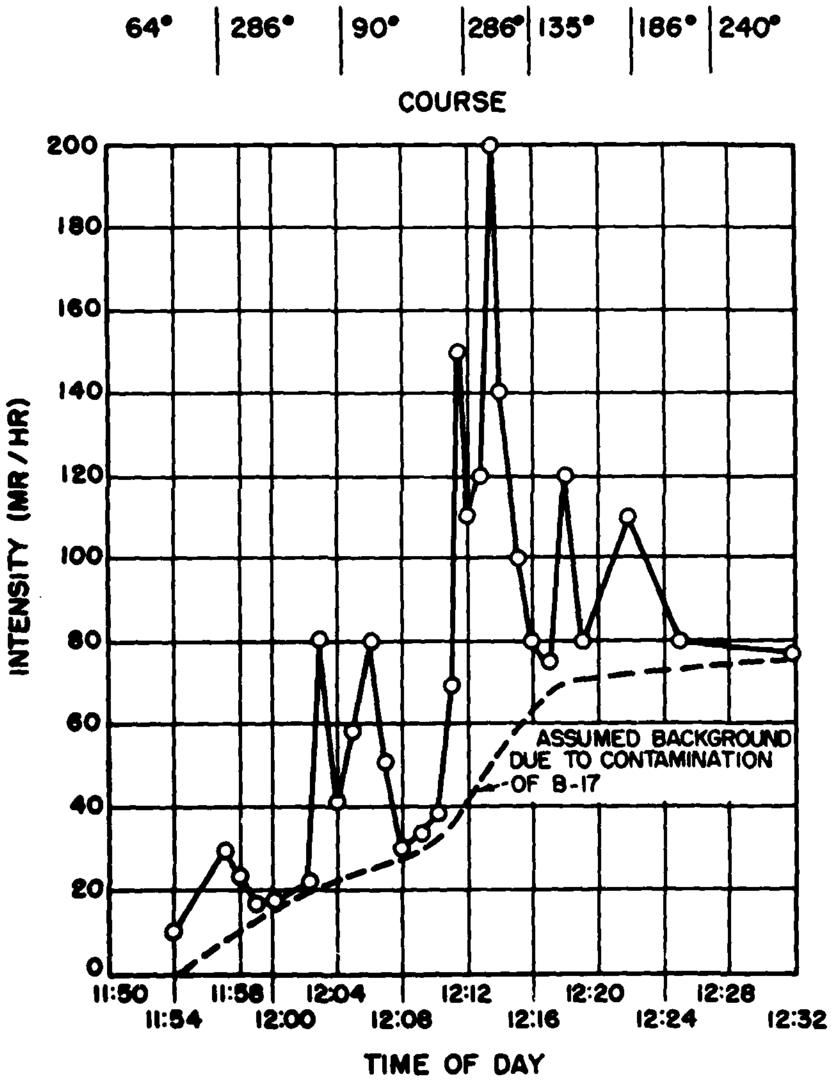

Fig. 2.6 Survey Meter Readings on B-17 Yellow How, 9 May 1951

Assuming that comparable fall-out occurred over 100 sq mi of surface from a layer of air 1 mile deep (a 75-micron particle falls 1 mi/hr according to Stokes' law), a total of 10^{12} large particles carrying 10^{12} μc in the original cloud is required. (This estimate of the number of particles is remarkably well supported by a spot count on radioautographs of the wing filters from the manned drone flown after George shot. These showed about 0.1 active particles/cu ft of air in the fall-out region.)

Supposing that the activity of the large particles was acquired by adsorption of small active particles, the loss of activity from the small-particle category would have been OM 10^{12} μc out of a total OM 10^{15} μc, a loss which would hardly be noticeable.

The existence of 10^{12} large particles in a cloud of 10^{18} small particles would require the counting of 10^{6} small particles to obtain a 50-50 chance of observing one large particle.

2.6.10 Biomedical Investigation

Urine samples from 125 individuals present during the Dog shot fall-out were analyzed in the TU 3.1.5 laboratory. By means of spiked samples, it was determined that the method would reveal the presence of 1.5×10^{-4} μc of mixed fission products in a urine sample. Three individuals were at first found to have slight activity, but their subsequent samples were negative. Four other individuals had about 2×10^{-4} μc, and similar results were obtained from their following samples.

Animals were sent to Los Alamos for analysis of lungs, liver, spleen, kidney, and bone. All tissues of all animals were found negative. The animals comprised 12 mice, 3 cats, and 2 dogs from Japtan and 1 dog from Parry shipped on D+2 day; 2 dogs from Eniwetok and 3 dogs from Parry and 2 dogs and 1 cat from Japtan shipped on E+2 day.

2.6.11 *Conclusions*

a. Very strong evidence was obtained that the Dog shot radioactive fall-out on Japtan, Parry, and Eniwetok islands, and on neighboring vessels, consisted of large particles, mostly 100 microns in diameter or larger.

b. Urinalysis of individuals and analysis of tissues of animals present during the fall-out support the conclusion that no harm was done.

c. The information obtained from cloud sampling in the past provided no hint of the possibility of such an event as the Dog shot fall-out on inhabited islands of the Atoll. Unless further analysis of the cloud sampling of Operation Greenhouse provides much more information of the kind needed, it will be clear that present techniques are not adequate for this purpose. In any event, the sampling aircraft cover only a limited part of the range of altitudes from which information is needed.

d. Some data were obtained that may be useful in predicting the intensity of heavy-particle fall-out in the future. Such predictions should be made with a great deal of caution. It appears that the quantity of airborne heavy radioactive particles may depend critically on certain factors about which little is yet known.

e. Of the various methods that were tried in an effort to obtain further fall-out information from Easy and George shots, the method of conducting an early low altitude aerial survey and sampling in the predicted fall-out area appears to be by far the most promising method (higher altitude surveys were not tried).

2.6.12 Recommendations

a. Unless Greenhouse sampling provides much more information than did former sampling about the radioactive heavy-particle content of clouds, more satisfactory equipment and techniques should be developed. Special attention should be given to the possibilities of aerial survey and sampling.

b. An effort should be made to learn more about factors such as soil stabilization methods and materials which may affect strongly the quantity of radioactive fall-out.

2.6.13 Item Shot Fall-out

The following information was obtained subsequent to the preparation of the report on which most of Sec. 2.6 is based. A cascade impactor was operated near the radiological safety building from I+11 hr till I+13 hr. All the radioactive material collected was isolated in seven particles, each of which was about 100 microns in diameter.

2.7 EXTERNAL RADIATION

Careful exposure records were kept for all personnel of JTF-3 who it was expected might

be exposed to radiation. The permanent record of such exposures for Operation Greenhouse is, as usual, the film badge. Film badges, with records indicating to whom each badge was issued, are stored at Los Alamos for reference in the event of any claim against the government which might arise in the future.

For personnel living on islands or ships at Eniwetok Atoll, the external radiation exposures indicated in Figs. 2.7 to 2.13 must be increased by the contribution of the fall-out, particularly after Dog and Item shots, bearing in mind the fact that personnel doing routine duties, sleeping, and eating indoors would receive only one third to one half of the dosage measured out in the open. It would be extremely difficult to estimate accurately the total exposures received by these personnel since film badges were not, in general, worn on home ships or islands.

In all cases, exposure records of personnel working in radioactive areas were scrutinized after each day's operation, and persons who approached or exceeded established tolerance levels were so informed and cautioned not to enter radioactive areas for certain lengths of time. In general, cooperation of test personnel with radiological safety instructions was excellent.

2.7.1 Dog Shot

In the early phases of the fall-out after Dog shot, radiation levels inside buildings were from one third to one half those found outside. To determine maximum possible integrated radiation doses, film badges were exposed outside the rear of the radiological safety building. These badges were replaced at 24-hr intervals and were supplemented by pocket dosimeters when decay had reduced the levels of activity. The build-up of the Dog day fall-out is shown in Fig. 2.1. Cumulative dose data are shown in Fig. 2.7. Assuming decay according to $t^{-1.2}$ and no loss from leaching, the maximum doses expected can be calculated as 2,210 mr to D+30 days and 2,705 mr to D+60 days.

Film badges were given to a group of monitors in TU 3.1.5 with instructions to wear them at all times except on missions to other islands. A similar group of badges was issued on Japtan. These films were developed on D+3 days 10 hr. The films indicated for Parry a mean dose of 890 mr and a range among the films of 560 to 1,400 mr, where the maximum that would be acquired had been estimated as 1,190 mr. The films for Japtan indicated a mean of 1,040 mr and a range of 825 to 1,600 mr, where the maximum had been estimated as 1,310 mr. The maximum value for Japtan was estimated from survey meter readings which were about 10 per cent greater than those on Parry. No comparable data are available from Eniwetok Island, but survey meter readings made early in the fall-out showed intensities of about two thirds of those on Parry.

2.7.2 Cumulative Radiation Dose Due to Dog Day Fall-out

Following the fall-out from Dog shot, cumulative dose data were obtained on Parry using photographic film badges and pocket ionization chambers. The readings were taken near the radiological safety building after a survey indicated that this was a representative area. Readings were discontinued on 14 May 1951 when the decay had reduced the daily dose to 20 mr.

Figure 2.8 shows the cumulative doses due to the fall-out from Dog shot and the subsequent lighter fall-out from Easy shot. The figures given represent doses which would have been received out-of-doors. Doses actually received were less than the figures given, depending upon the daily activities of the individuals.

2.7.3 External Radiation Doses to 27 April 1951

An analysis of all radiation exposures as shown by photographic film badges was made as of 27 April 1951. The exposure data presented represent only that obtained in various missions connected with tests Dog and Easy. The total radiation exposures will be higher than those given by about 1,600 mr, which is the estimated average integrated exposure received from the fall-out after Dog shot.

Film badge exposure data was available from 2,323 individuals and showed an average radiation dose of 355 mr. Excluding the three films mentioned in Sec. 2.3, the total doses ranged from 0 to 4,700 mr. Figure 2.9 shows the distribution of doses and indicates that a large number of persons received doses from 0 to 100 mr. This was due to two factors: First,

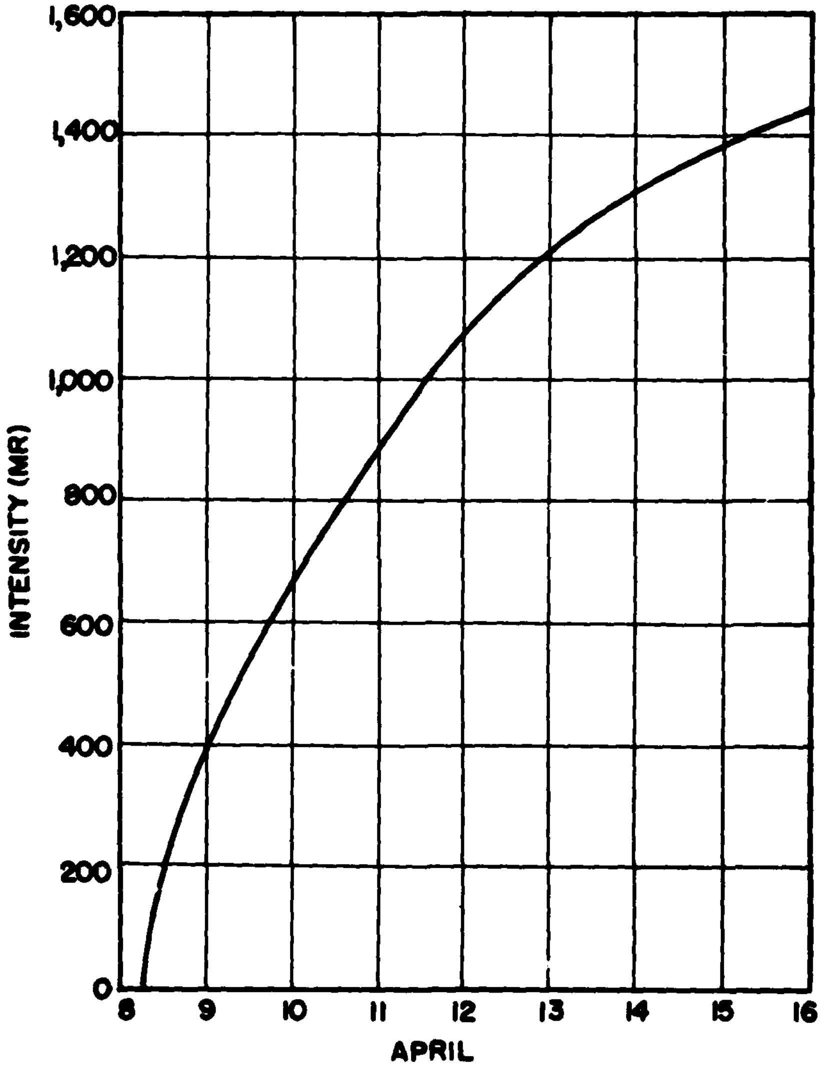

Fig. 2.7 Cumulative Gamma Doses, Dog Shot Fall-out

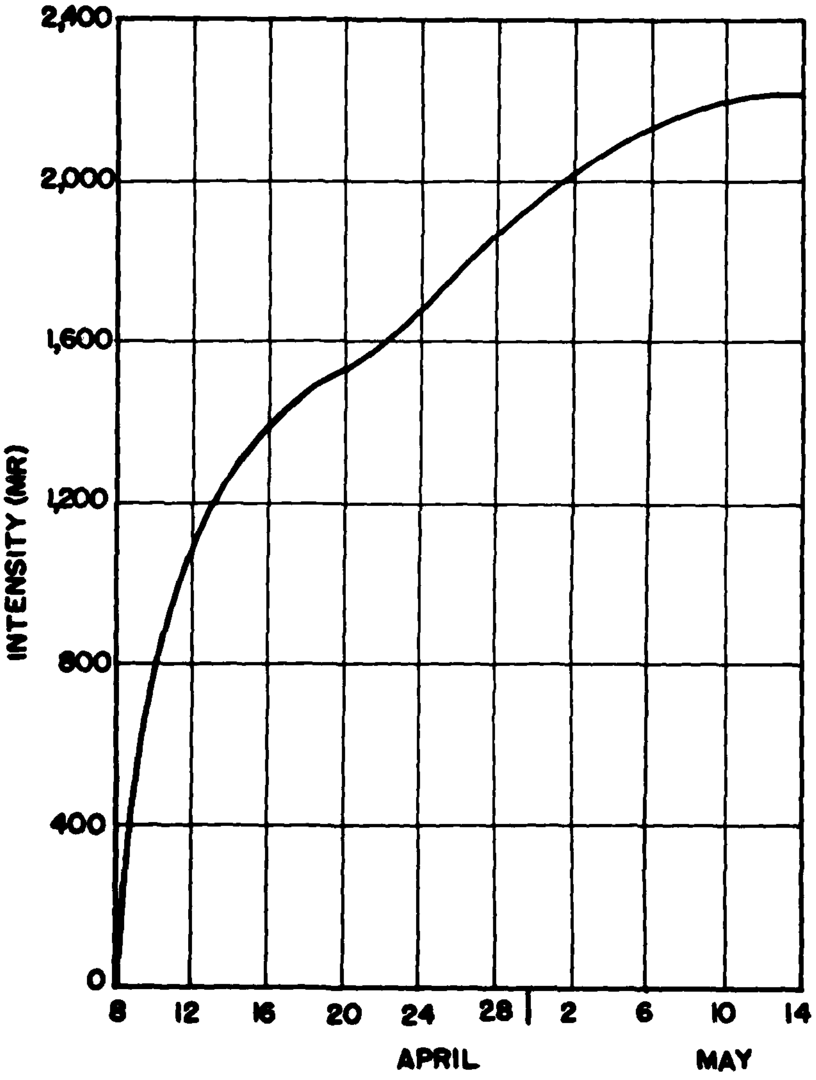

Fig. 2.8 Cumulative Gamma Doses, Dog and Easy Shots Fall-out

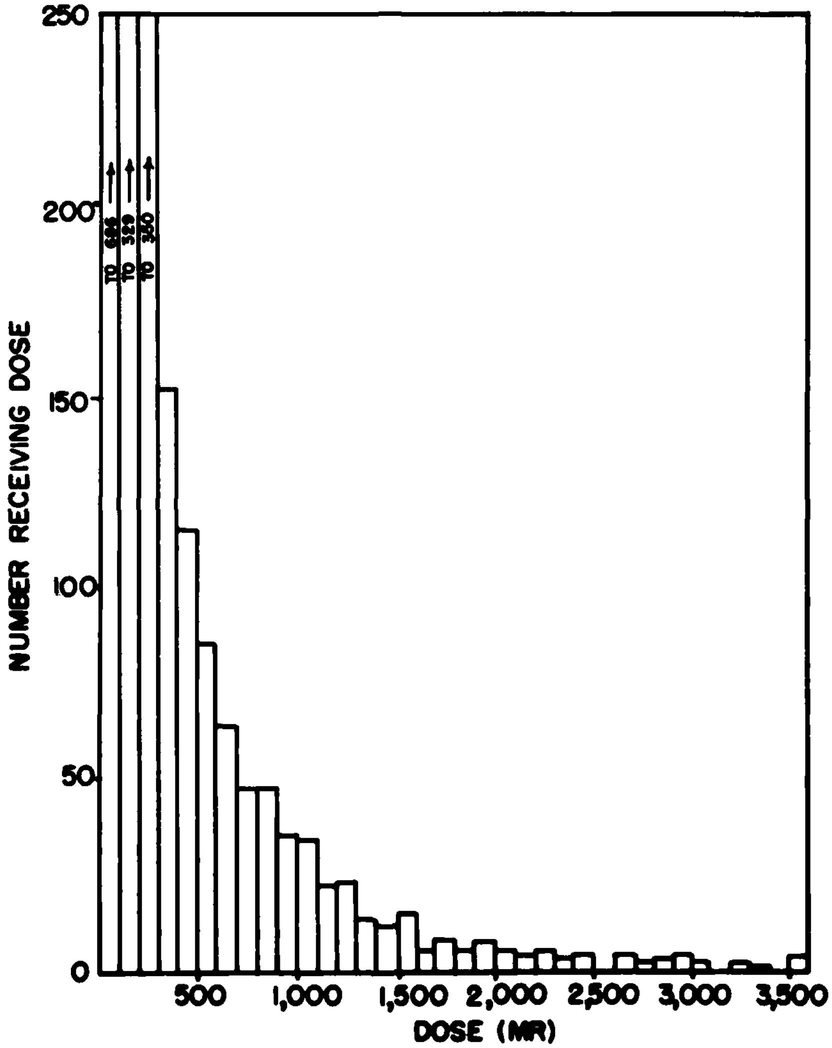

Fig. 2.9 Gamma Doses to 27 April 1951

film badges were worn by a relatively large number of casual visitors to the contaminated area, and, second, the limitations of photographic film dosimetry preclude the measurement of doses below 50 mr. If the lowest dosage group is excluded from the data in an attempt to obtain a better estimate of the average dose received by those actively associated with the tests, a value of 473 mr is obtained.

The members of TU 3.1.5 received an average radiation dose of 1,320 mr. This average was derived by considering all personnel of the unit, but, since some were laboratory personnel who received practically no exposure, the average dose received by the monitor group was somewhat higher.

The three films mentioned in Sec. 2.3 were from members of an LCM boat crew who, on E+2 days, made a trip from Parry to Engebi, Muzin, Bokon, and Teiteir. Three of the crew of four had film badges and pocket dosimeters. One man had an ionization chamber survey meter and acted as monitor for the party. He states that at no time did the meter read more than 40 mr/hr but that all 200-mr dosimeters were off scale at the end of the trip. Two civilian scientists making the trip had film badges which showed 170 and 185 mr. The clothing worn by the men with the high film badge readings showed only 3 mr at the end of the trip.

A series of tests was conducted to determine the accuracy, with fission product exposure, of film badge data compared with readings of quartz fiber pocket dosimeters. A Victoreen thimble ionization chamber, known to be reasonably energy independent, was used as a standard of comparison. It was found that a film badge reading of 100 to 200 mr had a low significance, owing primarily to the variable exposures received by all unused film badges during the Dog day fall-out. Readings above 400 mr agreed with the standard chamber within about 10 per cent and were considered to be reliable for doses equal to or greater than 400 mr.

2.7.4 External Radiation Doses to 15 May 1951

An analysis of all radiation exposures as shown by photographic film badges was made as of 15 May 1951. The exposure data presented represent only that received during various missions connected with shots Dog, Easy, and George. The total radiation exposures were higher than the figures shown by about 1,850 mr, which is the estimated average integrated exposure received from the Dog shot fall-out.

Film badge data available from 3,180 individuals show an average dose of 422 mr. Figure 2.10 shows the distribution of doses. If casual visitors are eliminated from the list, the average dose received by 2,235 persons is 600 mr. The members of TU 3.1.5 had received an average dose of 2,060 mr.

2.7.5 External Radiation from Fall-out following Item Shot

At approximately I+3 hr 20 min the gamma intensity recorder at the radiological safety building, Parry, showed a sharp rise followed by a drop to nearly the original reading. This "spike" was interpreted as the result of the passage overhead of an active cloud from which little material fell out. Several other spikes of activity appeared during the next few minutes, followed by a steady rise in activity due to fall-out, until about I+4 hr 45 min. Fall-out started again at I+8 hr and continued until I+13 hr 45 min. From I+16 hr the activity decayed according to a $t^{-1.2}$ law.

A continuous record of gamma ray intensities was maintained. Figure 2.11 shows the increase and decline of gamma intensity outside the radiological safety building as a result of the Item shot fall-out. Starting at I+12 hr, the integrated dose out-of-doors was determined by using pocket ion chambers and photographic film badges. These were placed at locations representative of conditions on Parry.

The integrated dose was determined by numerical integration of the intensity curve in the early stages of the fall-out and from direct dose measurements in the later phases. Figure 2.12 shows the cumulative dose curve.

An incomplete but reasonably representative survey of Eniwetok Island indicated that the fall-out situation there was almost identical with that on Parry. No data were available from Japtan.

Assuming that decay continued according to $t^{-1.2}$, it was possible to predict total doses for future times. For I+15 days the total expected dose out-of-doors was 7,370 mr, and for I+30 days it was 9,520 mr. It should be emphasized that these doses would result from the Item

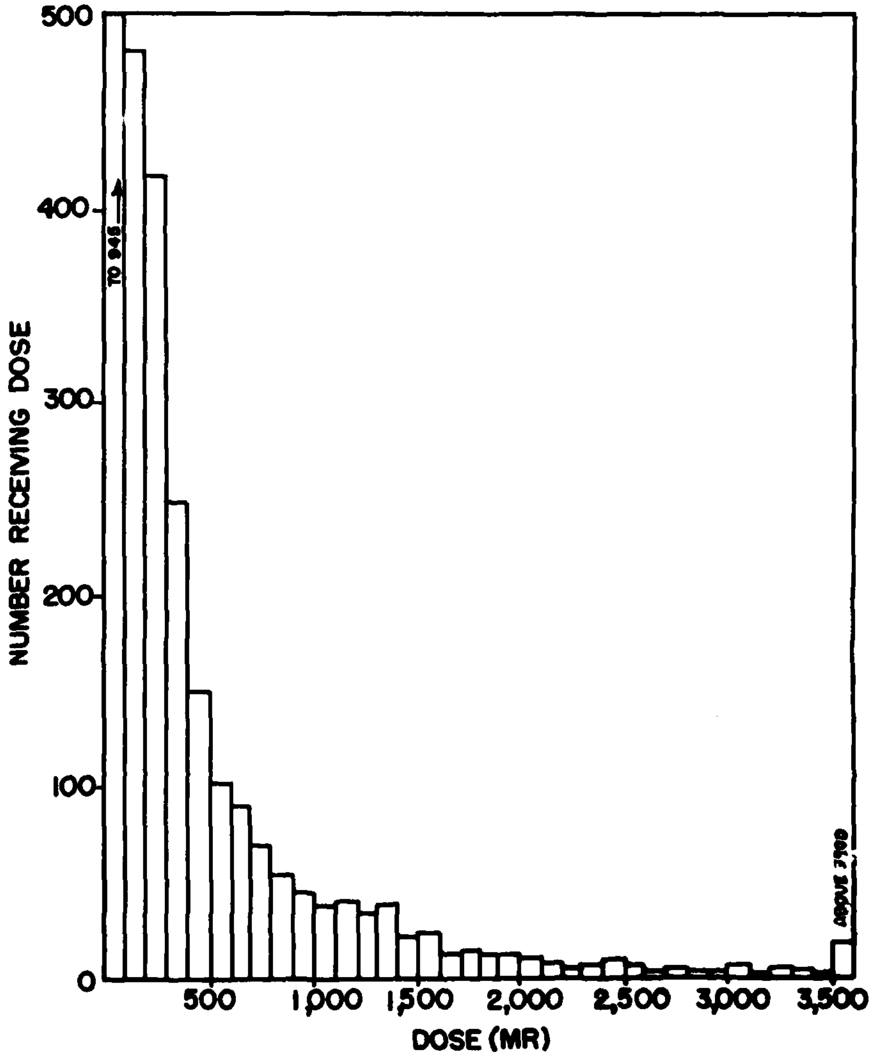

Fig. 2.10 Gamma Doses to 15 May 1951

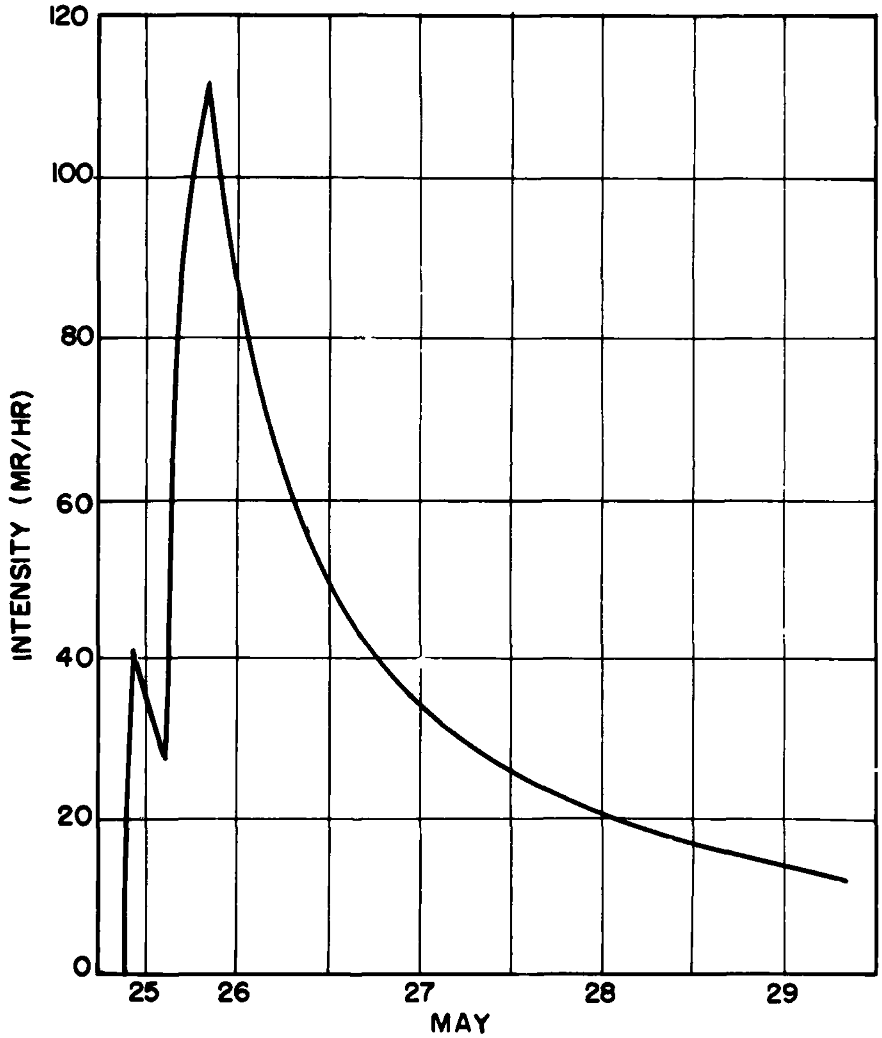

Fig. 2.11 Gamma Dose Rate, Item Shot Fall-out

[redacted]

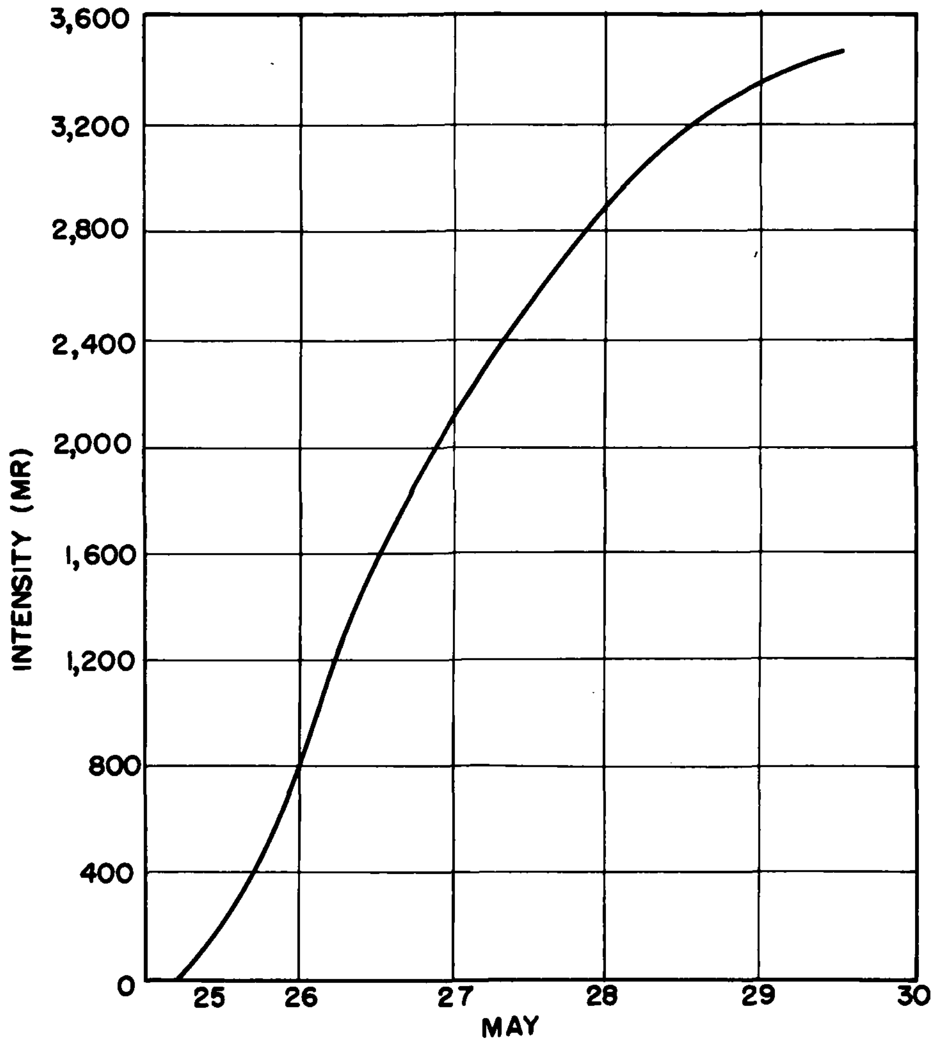

Fig. 2.12 Cumulative Gamma Doses, Item Shot Fall-out

[redacted]

shot fall-out alone and do not include doses from Dog and Easy fall-outs. The large doses to be expected result from the fall-out having occurred at such a late time. (See, however, the parenthetical note in the next to the last paragraph of Sec. 2.5.)

2.7.6 External Radiation Doses to 28 May 1951

An analysis of all radiation exposures as shown by photographic film badges was made as of 28 May 1951, the day before the departure of TU 3.1.5 staff from Eniwetok Atoll. The exposure data presented represent only that obtained in various missions concerned with the test program and do not include doses obtained from Dog, Easy, and Item fall-outs.

Film badge data from 3,335 individuals show an average exposure of 510 mr. Excluding 913 persons with exposures of 100 mr or less, the average was 710 mr. The distribution of doses received is shown in Fig. 2.13.

2.8 SUPPLY AND EQUIPMENT

In general, there were remarkably few supply and equipment problems for TU 3.1.5 during Operation Greenhouse. The only two items of equipment with which difficulty was experienced, the AN/PDR-T1B Radiac training sets and Mine Safety Appliance Co. dust collectors, have been discussed in Sec. 2.1.

Major items of equipment are listed in Appendix E. For a certain few of these items which might not be considered necessary for future tests, see the discussion of instrumentation in Sec. 2.9.7.

The original request by CTU 3.1.5 for 2,000 units of protective clothing was filled in adequate time. It was later necessary to order an additional 1,000 units, and these, too, were received in adequate time.

All survey meters were received in time except the AN/PDR-T1B's. Instruments were received without batteries; but batteries were drawn from general stock, and the instruments were completed and ready for calibration on time. Particular attention should be paid to the battery problem in future operations since some of the required batteries are not of common vintage.

Radiation counting laboratory equipment and photodosimetry equipment were complete and ready for operation upon arrival of TU 3.1.5.

The 15,000 photographic film badges requested were received on schedule. However, upon calibration it was found that the film packs leaked light around the perforations which formed the identifying numbers of the badges. This was overcome by wrapping the film badges in black photographic masking tape. Shortages of this tape, of which large quantities were required, necessitated special air shipment from the United States of additional supplies. For future operations, film packs should be carefully checked for light leakage at the point of manufacture.

Instrument repair tools were adequate after certain additional small tools were drawn from the AEC supply. For power tools considered desirable for future test operations see Sec. 2.9.

Requests for expendable supplies were filled on time and in adequate quantities except for certain batteries which were, from time to time, in short supply. Had radiation detection instruments arrived with batteries as originally requested, this situation would not have arisen.

Supply facilities in the Forward Area were adequate. Radiological safety personnel were able to fabricate certain items for which need always arises and for which the requirement cannot be foreseen. Such items, therefore, are seldom in stock.

In general, the materiel and supplies requested before the operation were adequate, with little oversupply and no known deficiencies.

2.9 INSTRUMENT OPERATION, REPAIR, AND MAINTENANCE

This section concerns the operation, repair, and maintenance of radiation detection instruments of the field survey type as well as some special modifications found desirable and useful. Some suggestions are included which may be helpful in future operations. Information was obtained through maintenance and repair work on all instruments used by TU 3.1.5, both of the field survey and laboratory type as well as field survey instruments used by other units. Repair and maintenance was conducted in a dehumidified room, in the radiological safety building, which was quite satisfactory. However, instruments were stored in a stock room having atmospheric conditions closely

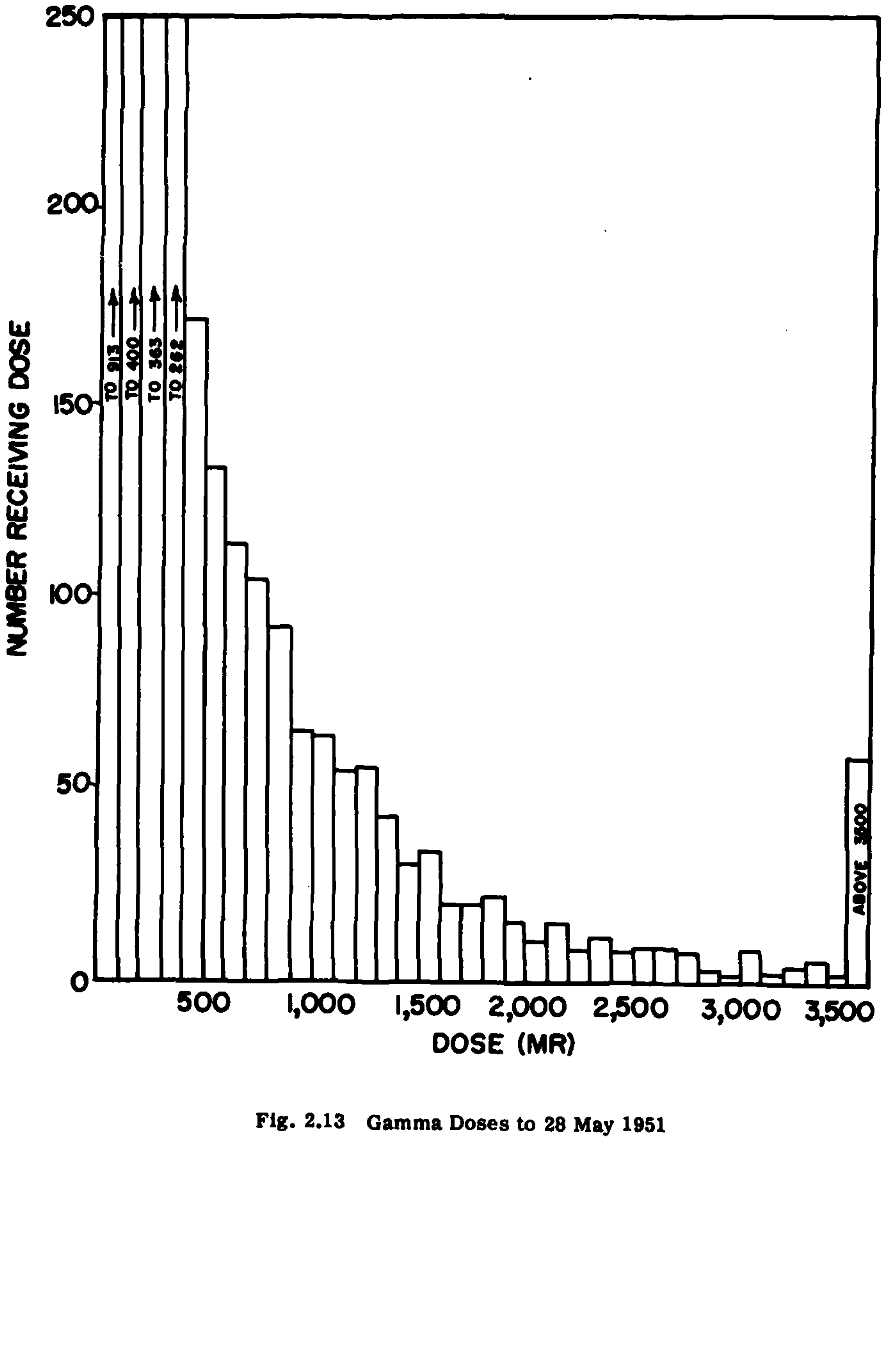

Fig. 2.13 Gamma Doses to 28 May 1951

approximating those encountered in the field. In this way most cases of improper operation due to high humidity became apparent and were remedied before field use of the instruments. Care was taken to check and calibrate each instrument periodically whether it was used or not, and additional checks were made before each shot. In the case of dosimeters and pocket chambers, a constant record of leakage was maintained.

The eight men assigned to this work were more than was required. Although many of this group had little previous experience with the particular types of instruments used, their training in electronics permitted them to learn easily. At times some of these men were used for communications work but only to a limited degree. Experience gained during Operation Sandstone was responsible for a much more efficient operation than would otherwise have been possible.

2.9.1 Pocket Dosimeters and Chargers

One hundred pocket dosimeters of 200-mr range were supplied by Beckman Instruments and 100 of a similar range by the Kelley-Koett Mfg. Co. A total of two hundred 200-mr dosimeters proved inadequate for this operation, and, although 35 additional instruments were borrowed, a total of 300 could easily have been used. These 200-mr dosimeters were considerably more reliable and caused less trouble than those used in Operation Sandstone. This was doubtless due, in great measure, to the methods used in sealing the chamber from moisture. It was difficult to tell whether leakage was a result of moisture or of defective insulation. Of the 200 dosimeters, 24 were eventually set aside as having excessive leakage. Calibration, in general, was good when a radium source was used. It was observed, however, that calibration and leakage both changed with time as the dosimeters were used. Also at times considerable differences were noted in readings of film badges and dosimeters used by monitors in the field. This may have been due to any of several factors such as defective films, energy dependence, monitor's technique, etc. A calibration test using radium as a source showed comparative readings to be within normal limits of accuracy. In the case of all dosimeters, the pocket clip was subject to rust in the test area climate. Provision should be made for rust-proofing this clip. No other part showed a tendency to rust or corrode. Little burning of scales due to concentration of sunrays was observed, although this was a factor at Operation Sandstone. No recognizable difference was noted in Keleket or Beckman dosimeters.

Two hundred 10-r Keleket dosimeters were supplied which proved adequate. Of this number, 17 were eventually set aside as having excessive leakage. In general, the foregoing remarks on 200-mr dosimeters apply to the 10-r instruments with perhaps one exception: A greater difference in film badge and dosimeter readings was observed occasionally after exposure in the field, although comparative checks with a radium source indicated results within normal limits of accuracy. In the case of the 200-mr and 10-r dosimeters, comparative checks were made with film badges, in the field, with fission product radiation as a source, and results were within normal limits of accuracy. In these tests a selected Victoreen model 300 Proteximeter was used as a standard *ion chamber.*

One hundred forty-four 50-r Keleket dosimeters were supplied. This number was considerably more than was required. Of these dosimeters, 23 were eventually set aside as having excessive leakage. Calibration and leakage tests were identical with other instruments, and, in general, the same remarks apply. Comparatively few of these instruments were used in the field by monitors, and none were actually required.

One hundred twenty-five Keleket and eight Beckman chargers were supplied. Probably not more than 25 were used. No trouble of any kind was experienced with either Beckman or Keleket instruments, although construction is somewhat different. A feature incorporated in the Beckman charger of automatically disconnecting the batteries when the dosimeter is removed will no doubt result in increased battery life. No choice, however, was indicated by users.

Two hundred 100-r and twenty-five 200-r Victoreen pocket chambers were supplied. Records were kept on leakage and calibration, but none of these instruments were used; hence, no information is available on their behavior in the field. Four minometer charger-readers were supplied by Victoreen and proved quite satis-

factory with one exception: The detent which engaged the groove in the pocket chamber did not guide the chamber in a positive manner when it was inserted in the tube. Unless an operator has had considerable experience he finds it extremely difficult to insert the chamber and turn it to its proper position.

Use of the dosimeters at Operation Greenhouse indicated a great need for 2- and 5-r instruments, which were not available. (It is extremely difficult to accurately measure doses for a 700-mr mission on a 10-r dosimeter, and some accuracy is lost in reading doses for a 3-r mission.) Many of the missions required exposures which exceeded the range of the 200-mr dosimeters but were too low to read with accuracy on a 10-r instrument.

2.9.2 Geiger Mueller Type Field Survey Instruments

For TU 3.1.5 two different types of Geiger Mueller (GM) field survey instruments were supplied: 75 Victoreen 263B beta-gamma survey meters and 35 El-Tronics SGM-18A beta-gamma survey meters. GM instruments that were serviced for other units included the AN/PDR-8B.

The Victoreen 263B instruments gave reasonably satisfactory service, with the exceptions noted below. Changes in manufacture as a result of experience gained at Operation Sandstone resulted in easy calibration and good linearity of resultant calibration curves. The parts are easily accessible for repair and maintenance. The following suggestions for improvement are offered: (a) Even though the size of the case has been reduced from that used with the 263A models, it still tends to be top heavy and will fall over easily in a boat or vehicle. The shape of the case could be improved, and the center of gravity should be lowered. (b) The probe has been greatly improved over that of the 263A, but the beta shield is still difficult to remove. This should be given some attention. (c) The life of the 1B85 Geiger tubes was unsatisfactory, and insufficient replacements were provided. (d) The case is not waterproof, and considerable moisture can accumulate inside the instrument, resulting, in most cases, in excessive meter readings. Such cases respond to drying with one exception: Moisture affects the 16 μf electrolytic condenser, C, which results in meter readings even though the switch is in the off position. To remedy this fault it was necessary to replace C in several instruments. In some cases the meter absorbed moisture, requiring a drying-out process. In the case of nine instruments the phone jack was wired incorrectly which resulted in no pulse in the earphones. After $2\frac{1}{2}$ months of use the following items represented replacements: thirty GM tubes, fifteen $1\frac{1}{2}$-volt batteries, thirty-three 300-volt batteries, eight $67\frac{1}{2}$-volt batteries, five amplifier units, and two meters. Corrosion was evident on some of the fittings, especially the metal portion of the carrying handles.

The El-Tronics SGM-18A instruments had several desirable design features; but most of the instruments received required changes in order to obtain good calibration, and some trouble was experienced with all tubes. The design of the case is good, and parts are easily accessible for servicing. However, GM tubes required considerable replacement as did 1U5 tubes. The instrument requires selected NC51 neon tubes which are difficult to obtain in quantities from normal stock supplies. The compensating register Rg was not of high enough value to allow correction for normal component variations. For this reason all 10,000-ohm potentiometers (Rg) were replaced with 50,000-ohm units which permitted a wide range of adjustment and resulted in correct calibration. Apparently some attention should be given to a redesign of circuits, especially the functioning of the NC51 neon tube.

While TU 3.1.5 was not equipped with AN/PDR-8B GM instruments, considerable servicing was done for other units equipped with them. The halogen filled GM tubes show great promise because of their long life and apparent rugged construction. After the modifications that are detailed below were made, the operation was very satisfactory, and the response was linear and could be directly read for all ranges. However, trouble was experienced with ruptured tube windows when the instruments were taken by plane to higher altitudes. Four instruments were found to have an open circuit in the "crimp" wire lugs connecting the V201 GM tube cable to the terminal board. This fault resulted in no response to radiation on the 0.5 and 5 mr/hr ranges. Twelve instruments were found to have no response or

erratic response on the 0.5 and 5 mr/hr ranges because of differences in operating characteristics of V201 and V104. Either the negative pulse from V201 was not of sufficient amplitude to trigger V101 consistently or the negative pulse from V104 was greater than that from V201 by a factor of from 5 : 1 to 30 : 1. Improved operation was obtained by carefully matching V201 and V104 tubes. It was also observed that the capacity of cables W201 and W101 were causing losses of pulse height up to 80 per cent. This loss was considerably reduced by substituting RG-78/v coaxial cable. Also by adding two $22\frac{1}{2}$-volt Minimax batteries in series with the supply to V201, operation was satisfactory in most instances. Full scale continuous or intermittent readings on all ranges and "hash" in the headphones were rectified by inserting a 5-megohm resistor in the positive 700-volt supply between the vibrator and the VR tube. Although the VR tube exhibited good regulating characteristics, the trouble would appear when the current exceeded 40 to 60 microamperes. Instruments with this fault were repaired by adding the 5-megohm resistor as noted above. In the majority of instruments the meter response was improved by increasing the time constant. This was done in several units by inserting a 2,000-ohm resistor in the meter circuit in the "read" position.

2.9.3 Ion Chamber Type Field Survey Instruments

Instruments of the ion chamber type supplied were as follows: 47 Victoreen 247A, 40 Victoreen 247E, 10 Victoreen 247H, and 60 AN/PDR-T1B. Construction and operation of all Victoreen instruments is much the same. The 247A and 247H instruments were used during Operation Sandstone, and previous reports have covered their operation. In general, the cases are bulky with the center of gravity high, making them somewhat difficult to handle and transport. The zero setting drifts over a considerable length of time before becoming stable, and the battery current drain is high. Nevertheless the instruments have been field tested and are considered to be quite reliable. A number of instruments were modified by drilling a small hole through the case and through the chamber. This allowed their use at high altitudes, in airplanes, without danger of chamber collapse. Calibration for pressure changes made them suitable for use in aircraft. Most monitors preferred the AN/PDR-T1B ion chamber, and consequently only a portion of the stock of 247 instruments were used Service included replacement of 10 chambers, 21 sets of batteries, 5 meters, 5 battery switches, 5 tubes, and 8 sets of minor parts and repair of 6 meter connection plugs.

The AN/PDR-T1B instruments were late in arrival but were placed in service immediately after checking and calibration. All units required adjustment of calibration control as well as grid current compensation potentiometers to correct for high readings. Attempts to set the calibration control in the open resulted in erratic readings, indicating a possibility that wind might build up a static charge on the chamber surface. The case of this instrument is well designed, and the instrument is handy to use and transport. These units were preferred over all other types by most monitors. Some difficulty was experienced in AN/PDR-T1A units with chambers apparently leaking when taken to high altitudes by plane. AN/PDR-T1B models are equipped with reinforced chambers, which seem to reduce this trouble. Athough the AN/PDR-T1B is relatively watertight, considerable trouble was experienced from moisture inside the case when the instrument was exposed to much rain. Usually drying corrected this trouble. Evidence of their rugged construction was shown when one instrument was run over by a truck. The handle and a rear portion of the case were bent out of shape; the instrument still continued to operate satisfactorily. The meter movement in a number of instruments was defective and required replacement or repair. Three such movements had open coils. Attention should be given the switch since this proved to be a source of trouble, resulting in erratic readings. Loose shaft bushings can also cause this erratic operation. Some of the batteries used are not of a common type and may be difficult to replace. If the instrument is handled roughly there is a tendency for the chamber to break loose from the supports. Several such instances were noted.

2.9.4 Alpha and Neutron Proportional Counters

Four Pee Wee proportional counters for alpha detection were supplied as well as two neutron detectors using modified Pee Wee instruments with boron lined tubes encased in

paraffin. No particular troubles were encountered with these units, and, although they were used very little, they performed quite satisfactorily after calibration.

2.9.5 Laboratory Instruments

These instruments, in general, included six Nuclear Instrument and Chemical Corp. scaling units with standard accessories (two equipped with gas flow alpha chambers) as well as two General Radio Co. counting rate meters and three Esterline-Angus Co., Inc., recorders. The instruments performed quite satisfactorily for this operation, although it was necessary to remove moisture from alpha chamber helium gas by passing it through chilled absolute alcohol before introducing it into the chamber. No major servicing was required other than an occasional tube replacement and changes to wire wound controls in the preamplifier of the alpha scaler.

2.9.6 Special Instruments

The only instruments supplied which were sensitive to beta radiation were low range Geiger tube units. A need for readings of beta intensities of a much higher order was found necessary, and for this purpose a modification of an AN/PDR-T1B instrument was made. An opening in the case below the chamber was made and covered with thin aluminum foil. Mechanical protection was provided by a protective wide mesh screen. The bottom of the plastic chamber was removed and replaced by a thin Aquadag-coated plastic sheet. After calibration this instrument proved to be an excellent field survey meter for beta, with quite a linear response.

To fill the need for a meter to measure 35-kv X rays, a 247A ion chamber instrument was employed, and an opening was cut in the case in front of the chamber. This opening was covered with a thin aluminum sheet and protected with a wide mesh screen. This modified instrument worked quite satisfactorily for the purpose for which it was intended.

It is thought that, for convenience in monitoring, an instrument which would read both instantaneous intensities of radiation as well as cumulative dose would be valuable. With this in mind, such an instrument was constructed. A 247A survey meter was used as the basis for the rate meter, and a Victoreen model 300 Proteximeter was used as the basis for the dosimeter. These two instruments were combined to form a single unit with one indicating meter. In operation, the meter normally indicates instantaneous intensities. However, at any time, a push button mounted on the handle may be pressed, and the meter will indicate the cumulative dose. This instrument proved to be most convenient and useful. Attention should be given to the production of similar models, perhaps built around different rate meter circuits and with dosimeter chambers having higher ranges than 200 mr, although the chamber may be charged at will. Also, a minimum of controls should be considered.

Instruments of several types were supplied which were not used in this operation. In all cases they were left over from Operation Sandstone. They included Victoreen 356 alpha survey instruments, Beckman MX-7 pocket alarms, Cambridge 17609 chargers, etc.

2.9.7 General Comments

At the start of this operation there was an inadequate supply of spare parts, as well as batteries, and some trouble was experienced in obtaining them. Delays in battery shipments were responsible for trouble with the Radiac training sets, but sufficient quantities were available later on. In general, sufficient numbers of hand tools and supplies were available after the operation got under way, but at the start difficulty was experienced in obtaining them. It is suggested that future operations include some small power tools such as a grinder, drill press, small lathe, etc. These were not available.

It is suggested for future operations that the instrument laboratory be set up and staffed, instruments be unpacked and placed in operating condition, and a calibration range be set up before monitors arrive. It is further suggested that all personnel in the instrument laboratory be given an oportunity to inspect all instruments to be used and to become familiar with them before the field operation starts. They should at least be given a list of instruments in advance along with instruction books describing their construction.

In conclusion, it might be said that work in the instrument laboratory proceeded more efficiently and with less trouble by far than in any other operation with which the writer has been associated. This probably was in great

measure due to experience gained in Operation Sandstone, as well as to the fact that improvements in instruments resulted in fewer problems of repair and maintenance.

2.10 DOSAGE RECORDS

The section charged with the developing and reading of the film badges consisted of five men, an adequate number. Four men could handle this job about as efficiently and without too much difficulty under the same circumstance encountered at Operation Greenhouse. The recording section should have at least two clerks plus a man to handle the issuance and collection of the films. This latter man could have additional duties in an adjoining section, such as supply, though he must be nearby at all times.

The officer in charge of the photodosimetry section would do well to study a similar section in the United States prior to arrival at the test site. The forms suggested below are the result of trial and error, and undoubtedly better and more efficient ones can be devised. The photographers reported the film badge dosimetry readings by film badge number on a simple lined sheet with columns for the readings. Our section used a sheet similar to the form given here as Example A.

Film No. 1 represents the most sensitive film in the three-film badge, and film No. 2 represents the next most sensitive. The No. 3 film was read so seldom that no space was provided for its readings. The column headed gamma was used to record the actual densitometer reading obtained on the lead shielded portion of the film. The "true" reading is the actual reading from which the basic density reading of the film has been subtracted. The first column headed mr is the true densitometer reading translated to milliroentgens from a calibration curve made the same day. The beta column is the actual densitometer reading taken from the unshielded portion of the film, and the second column headed mr represents a figure taken from a calibration curve calculated from the same unshielded portion of the film. These columns are not all essential, but they did prove useful when it was necessary to refer to specific film badges.

The form used in the issuance and collection of film badges was essentially as shown here as Example B.

This form was used both in the file book retained at the issuing counter and by the person

EXAMPLE A

	Film No. 1						Film No. 2					
Badge No.	Gamma	True	mr	Beta	True	mr	Gamma	True	mr	Beta	True	mr

EXAMPLE B

Date Issued	Issued to	Film Badge Number	Name of Person Wearing Badge	Dosimeter Reading	Date Rec'd	Film Badge Reading	Check

drawing more than one film badge when he did not know the specific names of the persons to be given each film badge. The form given the person drawing badges was stamped with the badge numbers in sequence at the time of issuance. These names were added to the sheet as they were reissued by the drawer. When large numbers of badges were issued to a single person, the returned sheets were inserted in the retained file in place of the retained sheets in order to avoid the recopying of a large number of names.

The retained file consisted of the forms described above placed in books with Acco fasteners. These sheets had the film badge numbers stamped in sequence in the appropriate column. As a badge was issued, the date issued was filled in, as was the issued to column in case several badges were issued to a single person. The name of the person wearing the badge was filled in with the time if it was known. On return of the badges, the names were then transcribed from the sheet returned, or the sheet itself was inserted in place.

The dosimeter reading column was filled in by the wearer if a dosimeter was carried. The film badge reading (in mr) column was filled in as the film badge readings came from the photographic laboratory. The last column was used by the recording section to check each name as the readings were transcribed to the file cards of each individual. An additional column might be used for the name of the organization, as it was extremely difficult to obtain this information at times.

The file cards used for the permanent records of each individual were 5 by 8 in., preferably ruled, with columns shown here as Example C.

The columns are self-explanatory, gamma readings only being recorded routinely.

The greatest difficulty encountered in this filing system was the lack of an initial list of names of persons on whom records had to be kept. A Kardex system was used, but the addition of large numbers of cards at busy times reduced the efficiency of the system tremendously. If initial lists are unavailable, it is believed that a system of loose cards in a file box would be better, so that new cards could be added without continuous reshuffling of the Kardex system.

EXAMPLE C

Date	Badge No.	Reading (mr)	Accumulative Dose	Date	Dosimeter Reading	Accumulative Dose
Name				Organization		

Chapter 3

Résumé

3.1 INTRODUCTION

The radiological safety unit for Operation Greenhouse performed a much more efficient job than was performed on any of the preceding tests. This was primarily due to two factors: (1) availability of better trained and more experienced personnel, and (2) closer integration of the radiological safety unit with the over-all scientific program. The latter was by far the more important. Regardless of the training of the individuals in a unit, the job cannot be efficiently performed unless they are well indoctrinated in the over-all program.

The personnel of the unit was adequate in numbers. The group arrived about one month before the first test. It was felt by some of the monitors that two weeks before would have been sufficient. However, when all the factors involved, such as acclimation, familiarization with the various instruments, and personal contacts with the other workers, are considered, one month appears to be about the proper time.

Instrumentation was adequate, and in general the instruments proved to be more reliable than heretofore, because of better design and better construction. Far less repair work was required than on previous operations. All supplies, clothing, and tools were adequate.

It is felt that the assignment of responsibility for radiological safety to the various task groups was in error. Even though the utmost cooperation between all groups was exercised, there was an occasional lack of coordination which would not have existed if the responsibility had been in one group.

In future testing much thought and consideration should be given to re-entry time for scientific recovery on various test islands. It is felt that the personal enthusiasm on the part of some experimenters caused the recovery of data sooner than was necessary for successful implementation of the experiment. This resulted in exposure of recovery and monitor personnel which could be avoided if time of recovery were dictated by scientific need rather than emotion.

The problem of establishing a certain dosage allowance should also be given further study. Because of the ever-changing weather conditions at Eniwetok, it should be assumed that fall-out must be accepted. To establish a limit of 3 r per test and then have more than this as a result of fall-out alone creates confusion in the mind of both the military and the civilian worker.

3.2 CONCLUSIONS

1. The organization, training, and operations of TU 3.1.5 were adequate.
2. Personnel, supplies, and instrumentation were adequate.

3.3 RECOMMENDATIONS

1. That in future testing all radiological safety work be performed by one unit, under the Commander of the Scientific Task Group.
2. That further study and consideration should be given to re-entry time. Early re-entry should not be made unless it is essential to save valuable data.
3. That further consideration toward raising established permissible dosage during test operation be subjected to study.

Appendix A

Shot Island Surveys, Dog

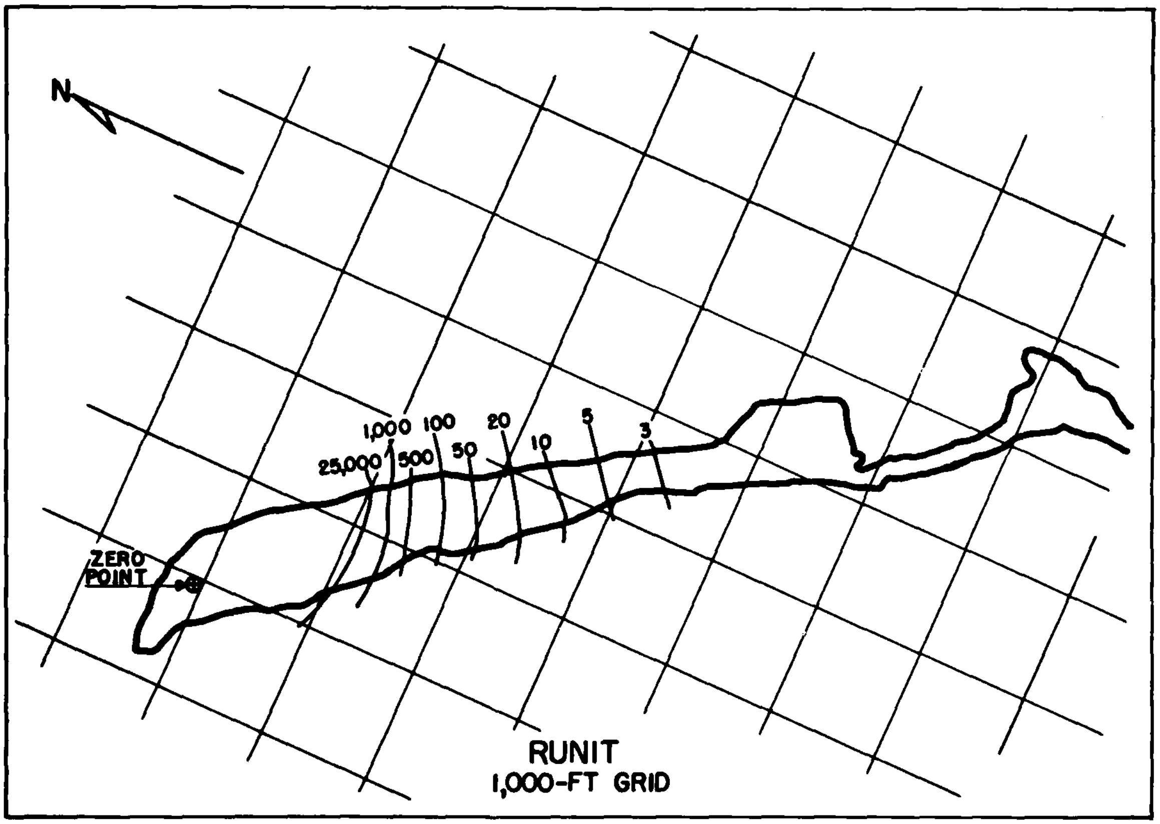

Fig. A.1 Runit Survey, 0900 9 April 1951, D+1. Intensities are mr/hr.

[redacted]

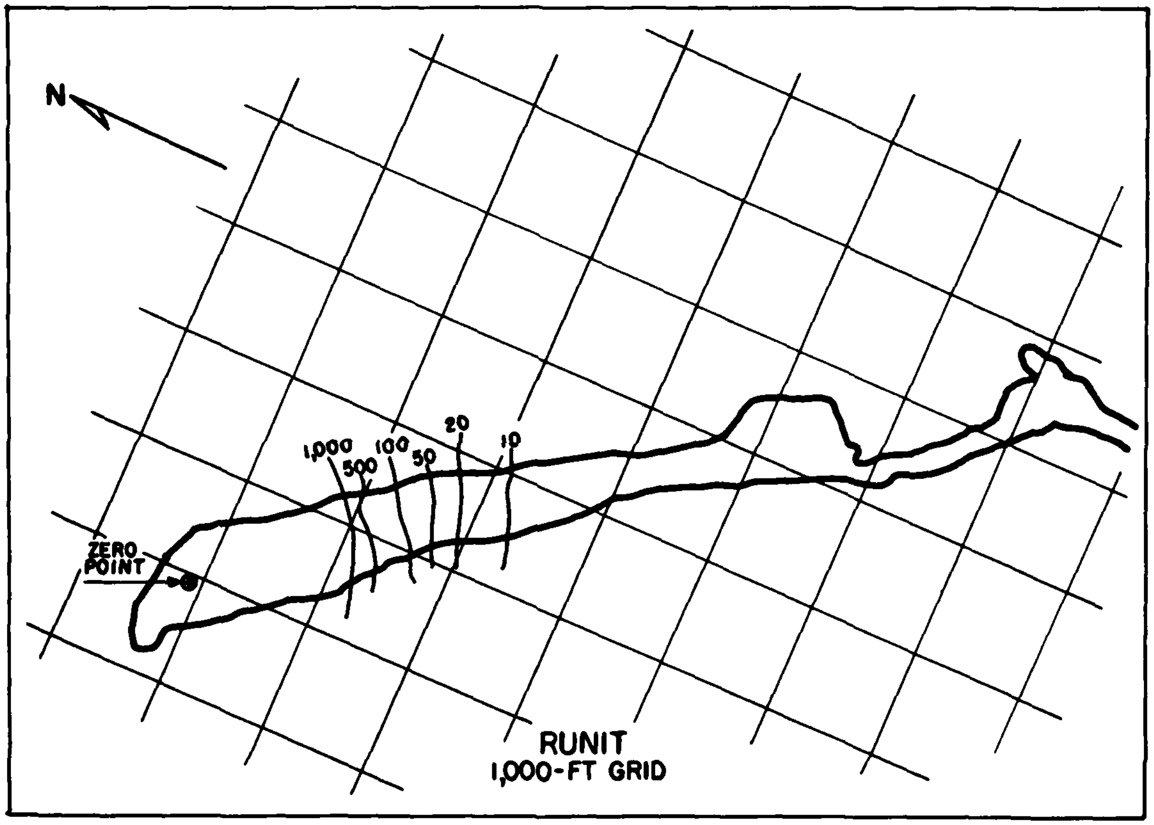

Fig. A.2 Runit Survey, 0900 10 April 1951, D+2. Intensities are mr/hr.

[redacted]

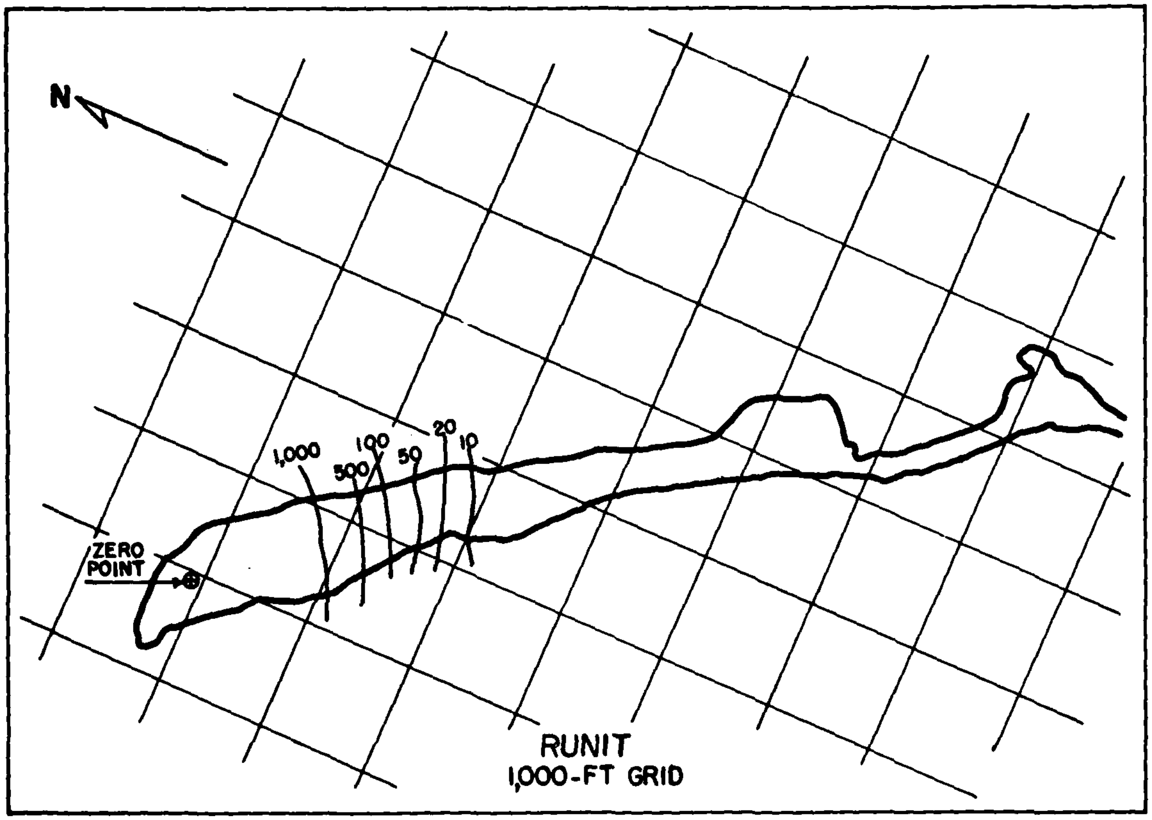

Fig. A.3 Runit Survey, 0930 11 April 1951, D+3. Intensities are mr/hr.

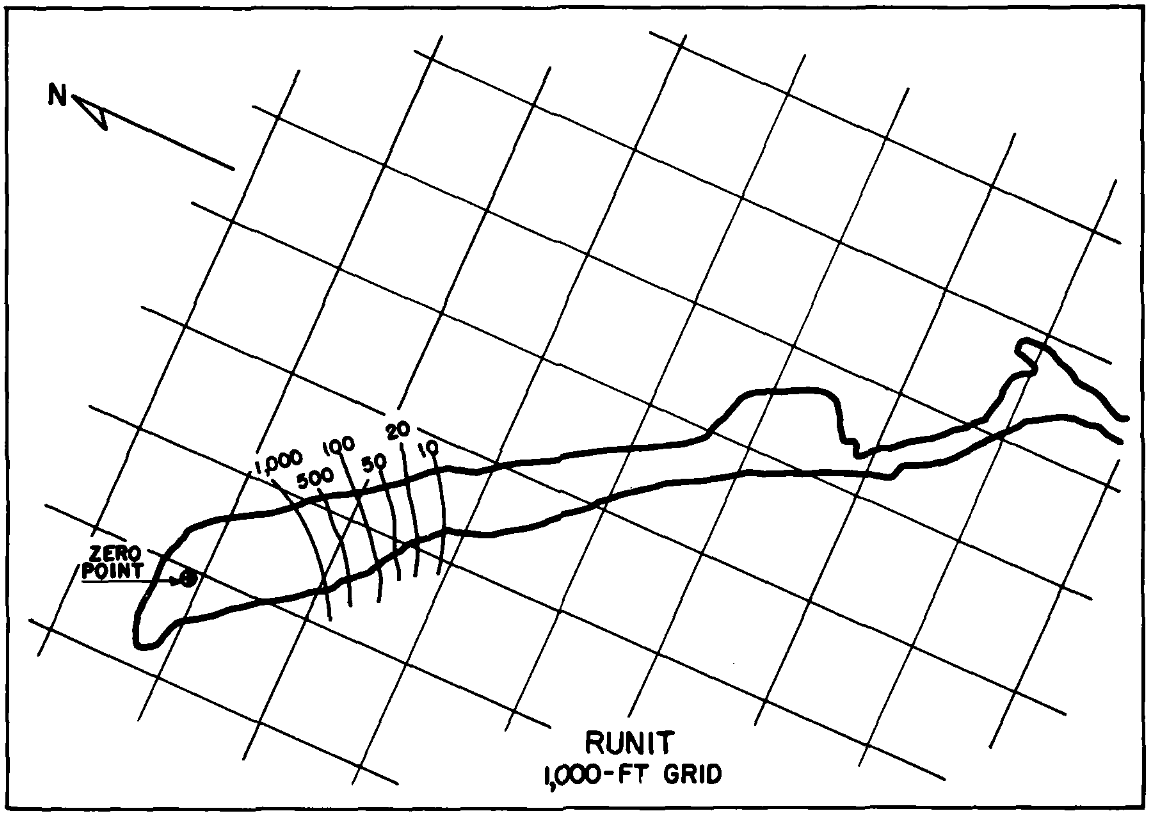

Fig. A.4 Runit Survey, 0830 12 April 1951, D+4. Intensities are mr/hr.

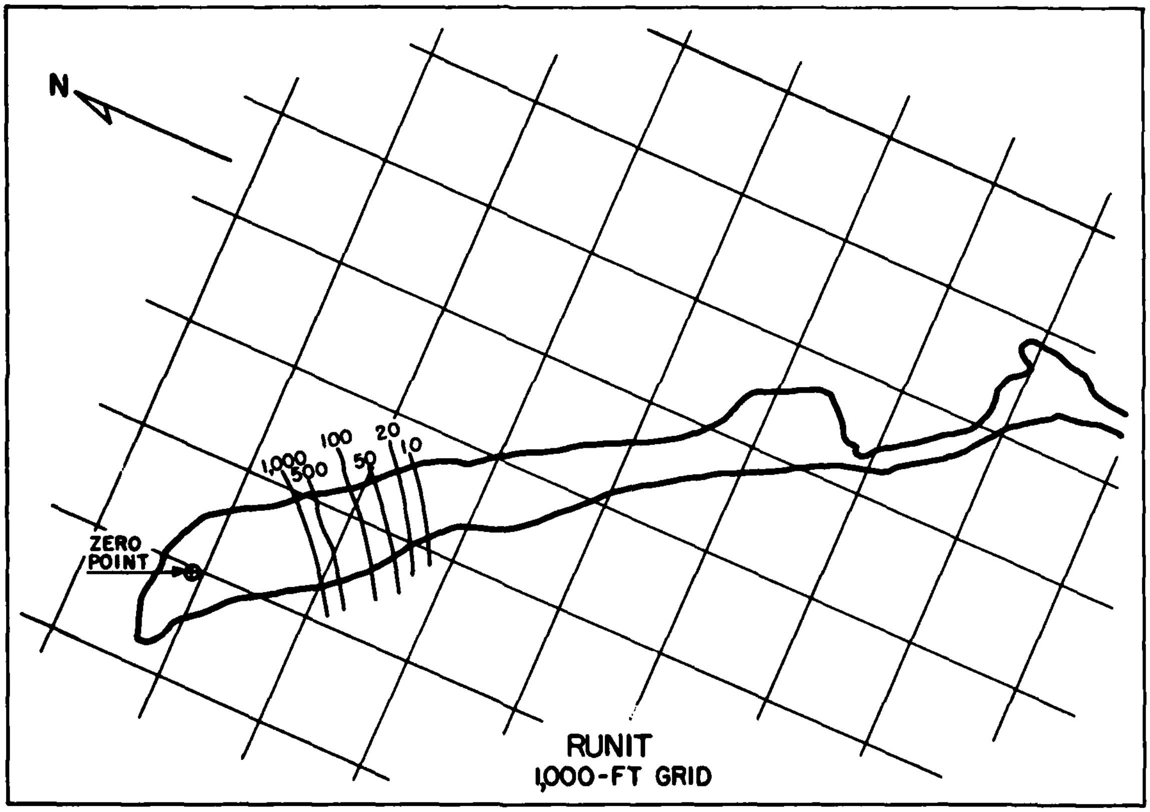

Fig. A.5 Runit Survey, 0930 13 April 1951, D+5. Intensities are mr/hr.

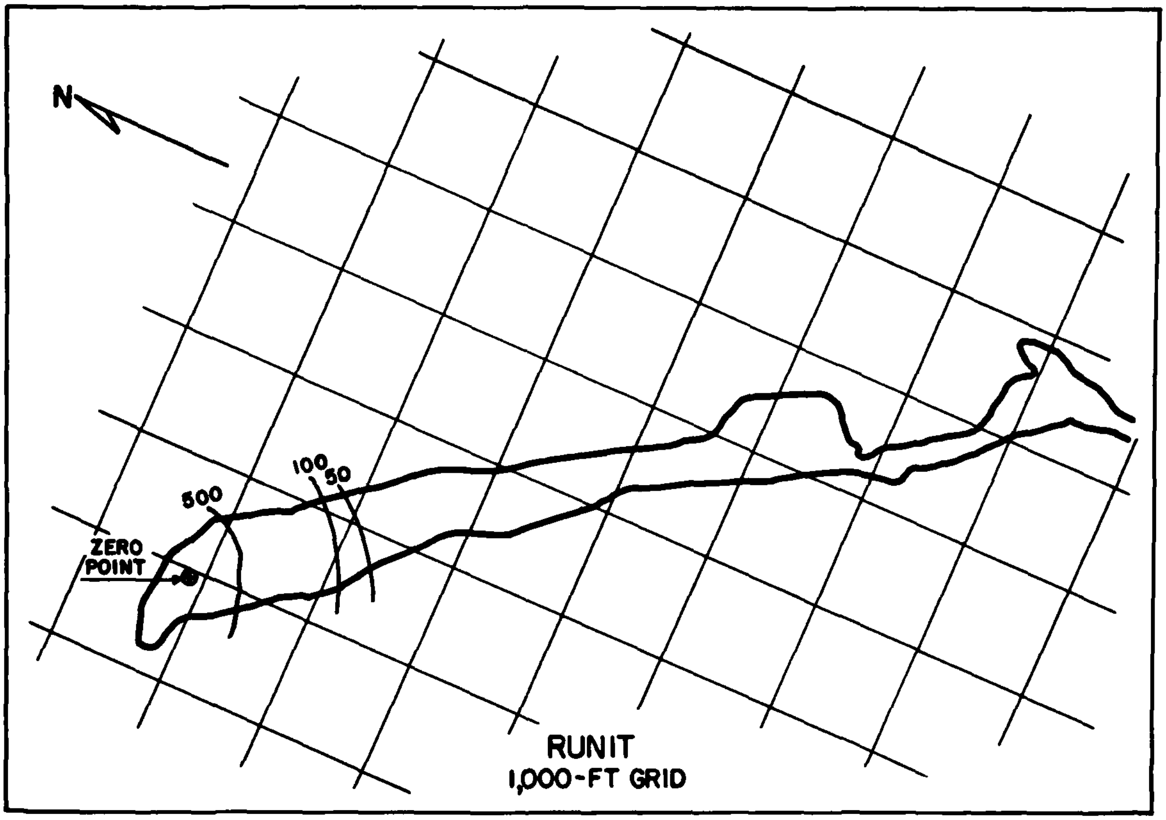

Fig. A.6 Runit Survey, 2 May 1951, D+24. Intensities are mr/hr.

Appendix B

Shot Island Surveys, Easy

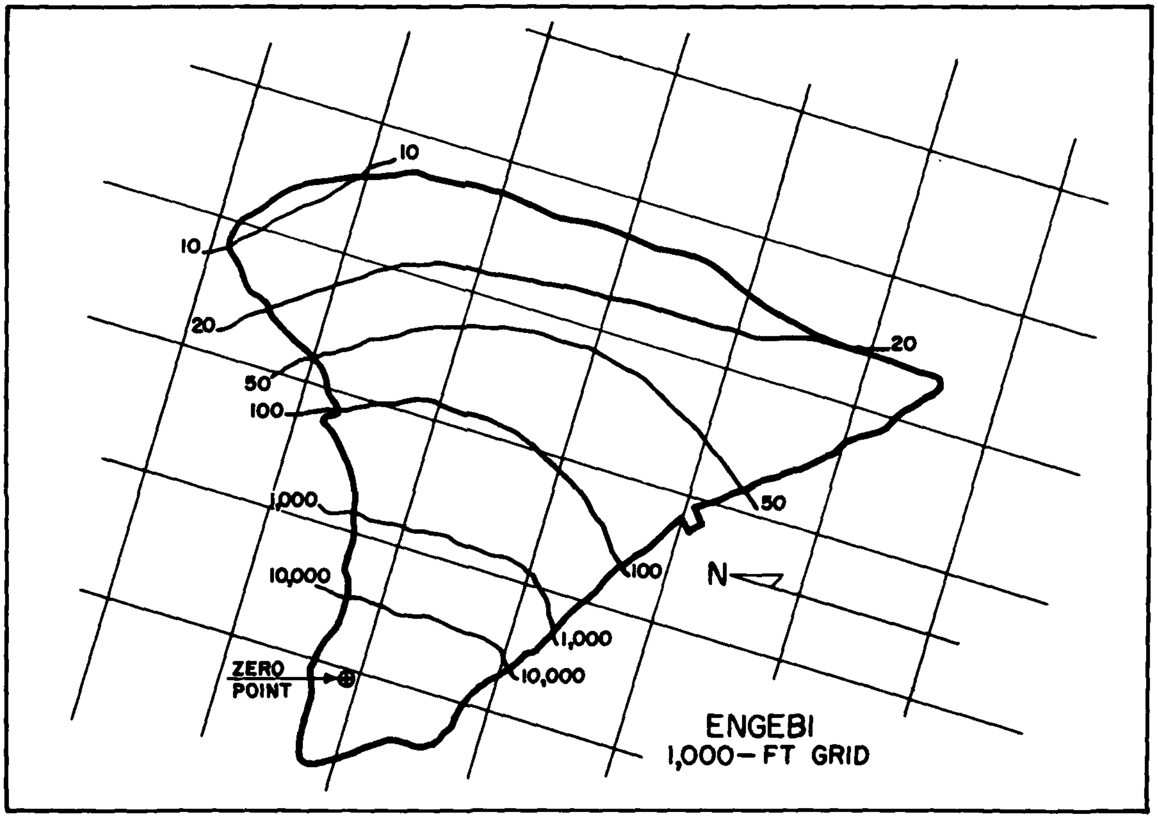

Fig. B.1 Engebi Survey, 1030 22 April 1951, E+1. Intensities are mr/hr.

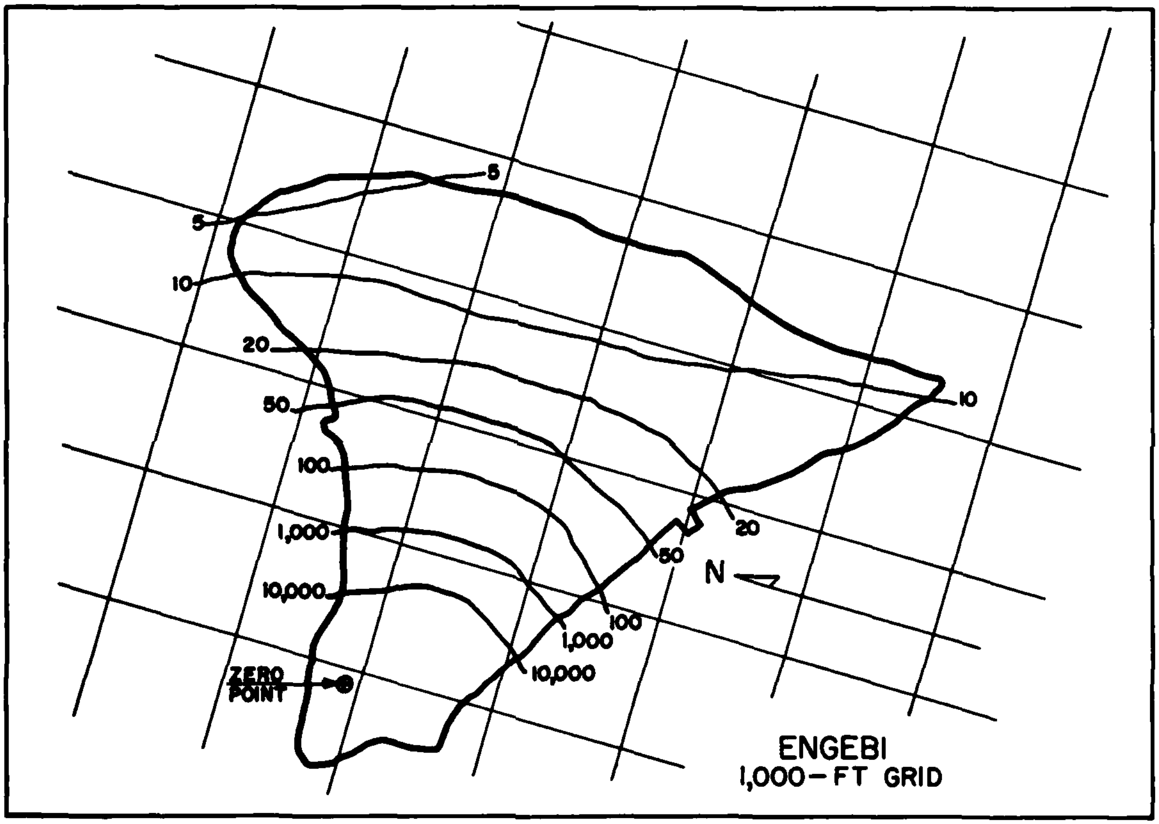

Fig. B.2 Engebi Survey, 1300 23 April 1951, E+2. Intensities are mr/hr.

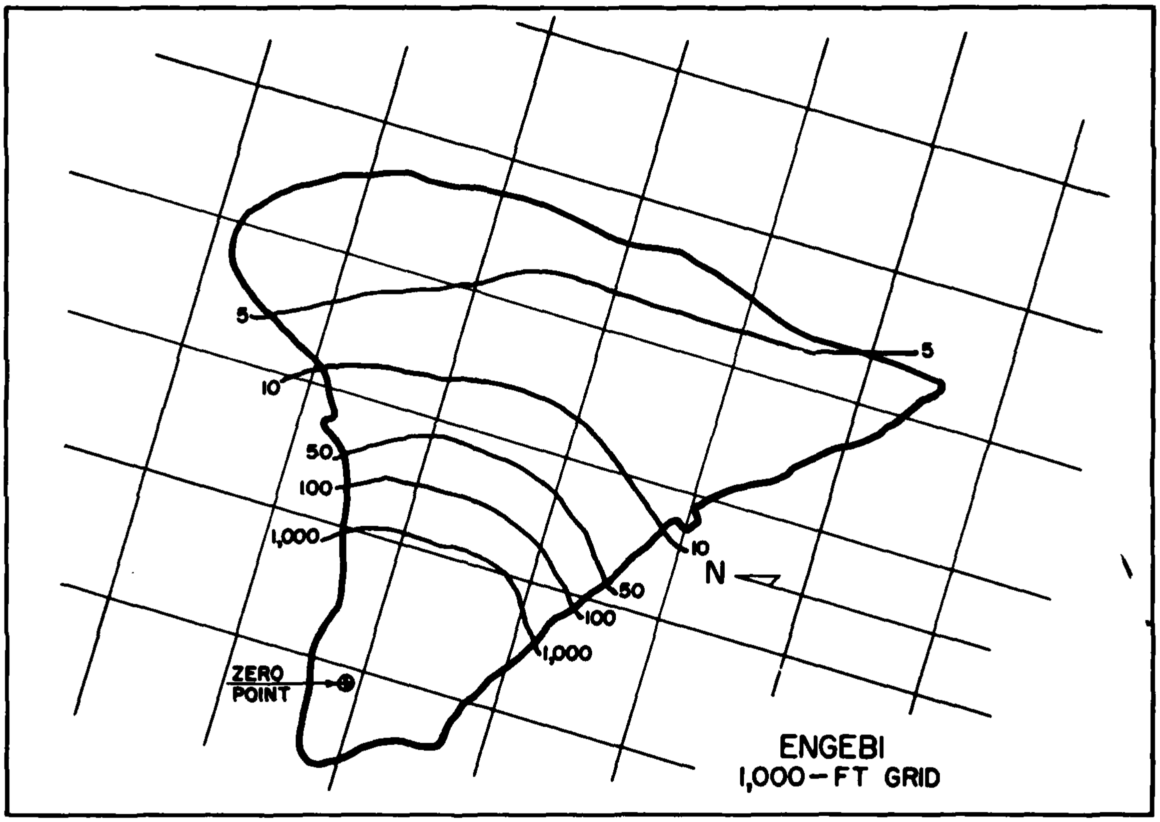

Fig. B.3 Engebi Survey, 1300 24 April 1951, E+3. Intensities are mr/hr.

[redacted]

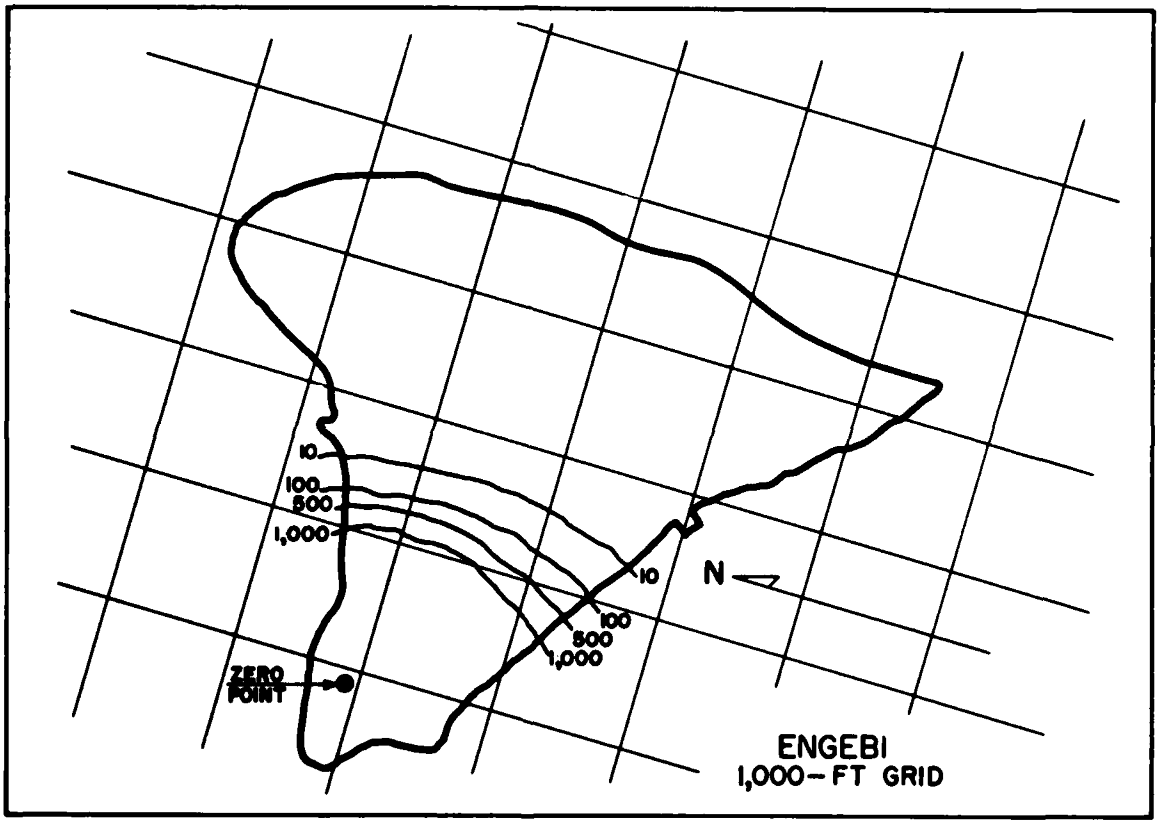

Fig. B.4 Engebi Survey, 26 April 1951, E+5. Intensities are mr/hr.

[redacted]

[redacted]

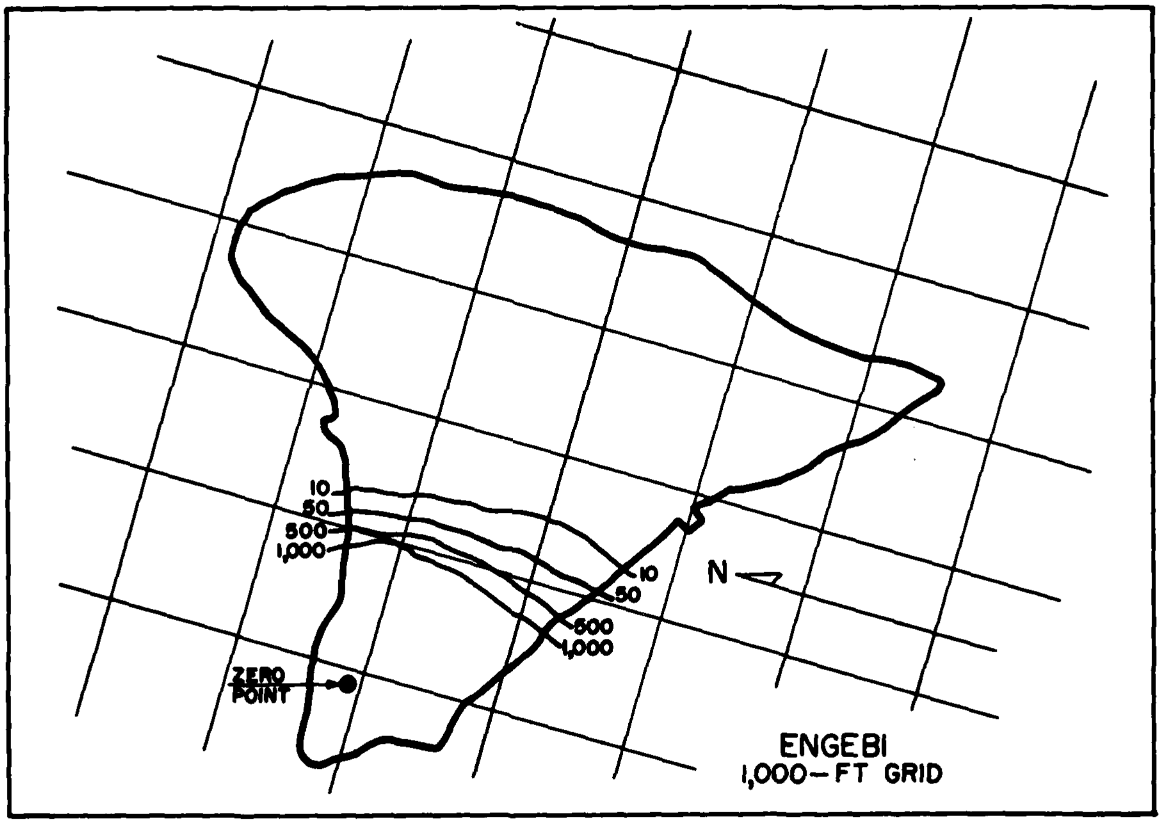

Fig. B.5 Engebi Survey, 28 April 1951, E+7. Intensities are mr/hr.

[redacted]

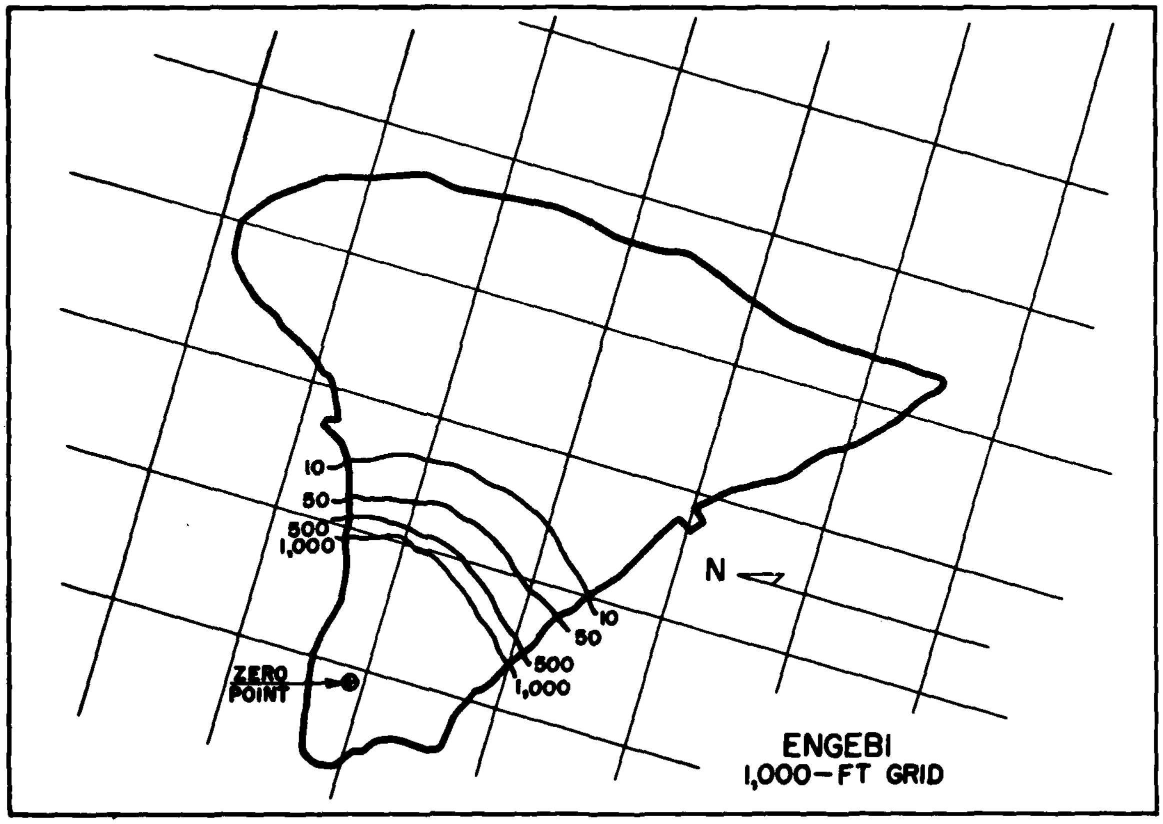

Fig. B.6 Engebi Survey, 30 April 1951, E+9. Intensities are mr/hr.

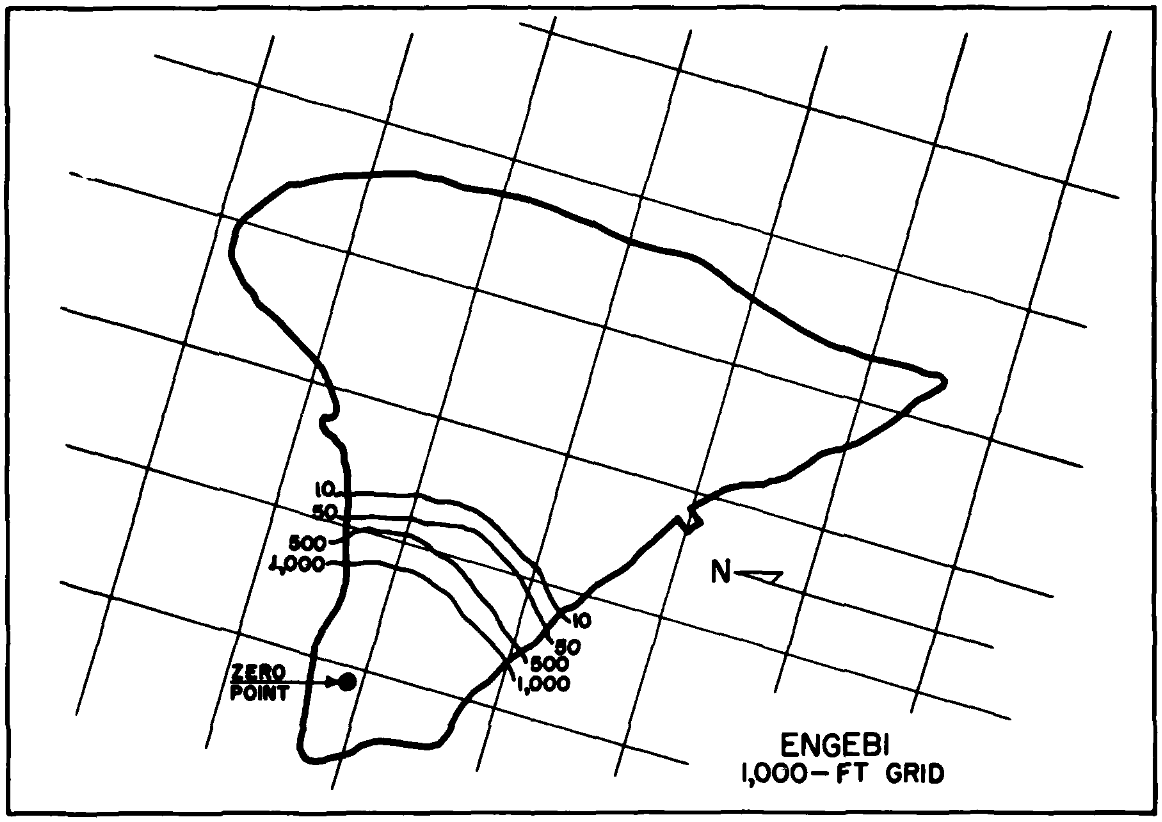

Fig. B.7 Engebi Survey, 2 May 1951, E+11. Intensities are mr/hr.

Appendix C

Shot Island Surveys, George

[redacted]

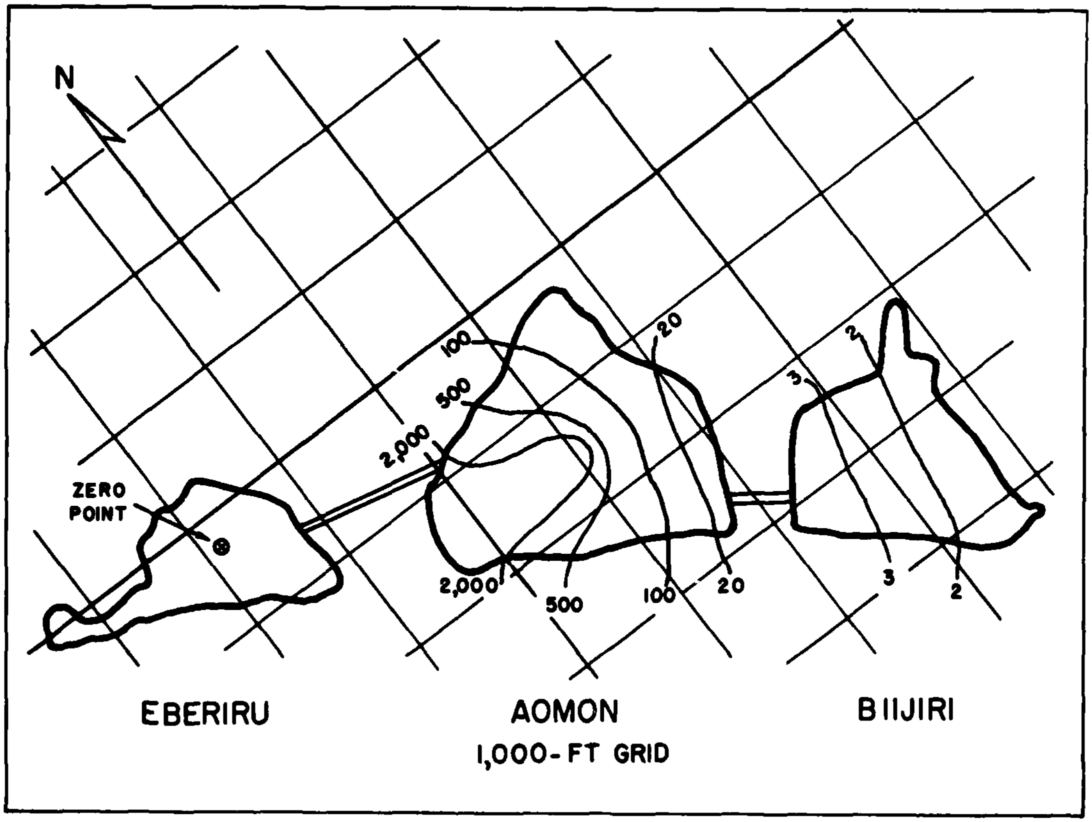

Fig. C.1 Aomon Survey, 1000 10 May 1951, G+1. Intensities are mr/hr.

[redacted]

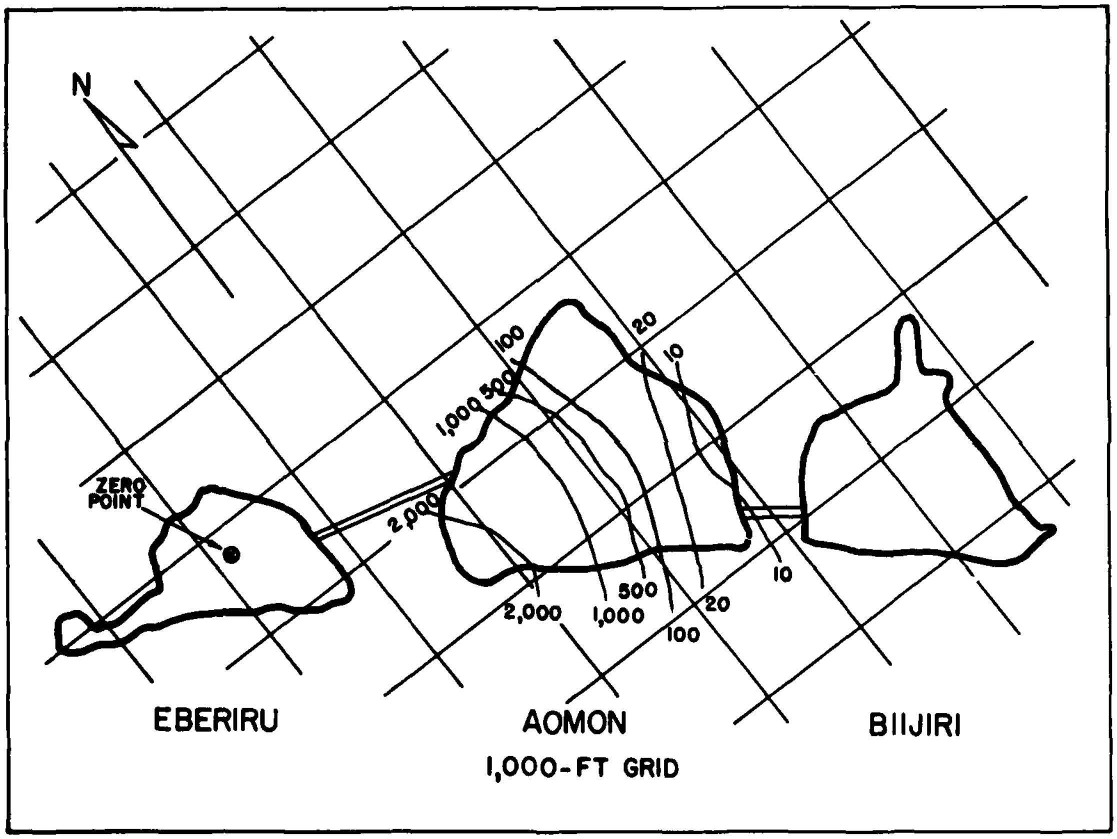

Fig. C.2 Aomon Survey, 1000 11 May 1951, G+2. Intensities are mr/hr.

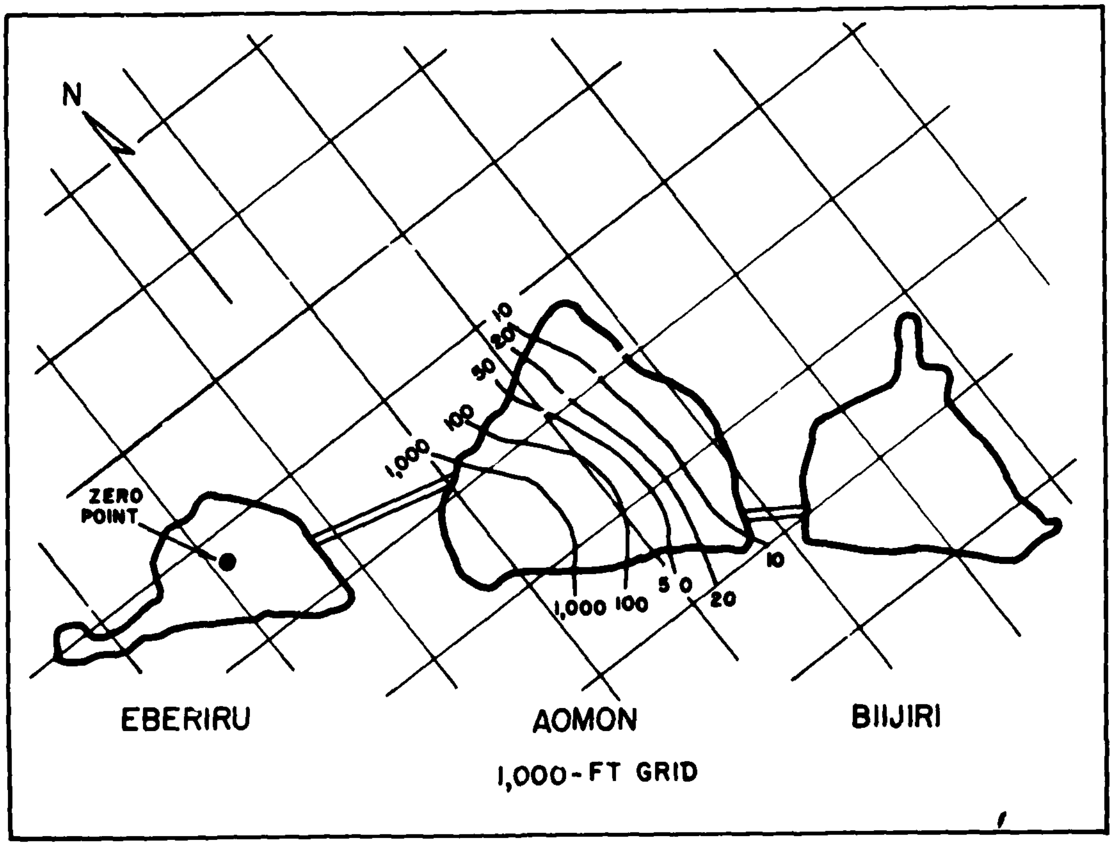

Fig. C.3 Aomon Survey, 12 May 1951, G+3. Intensities are mr/hr.

[redacted]

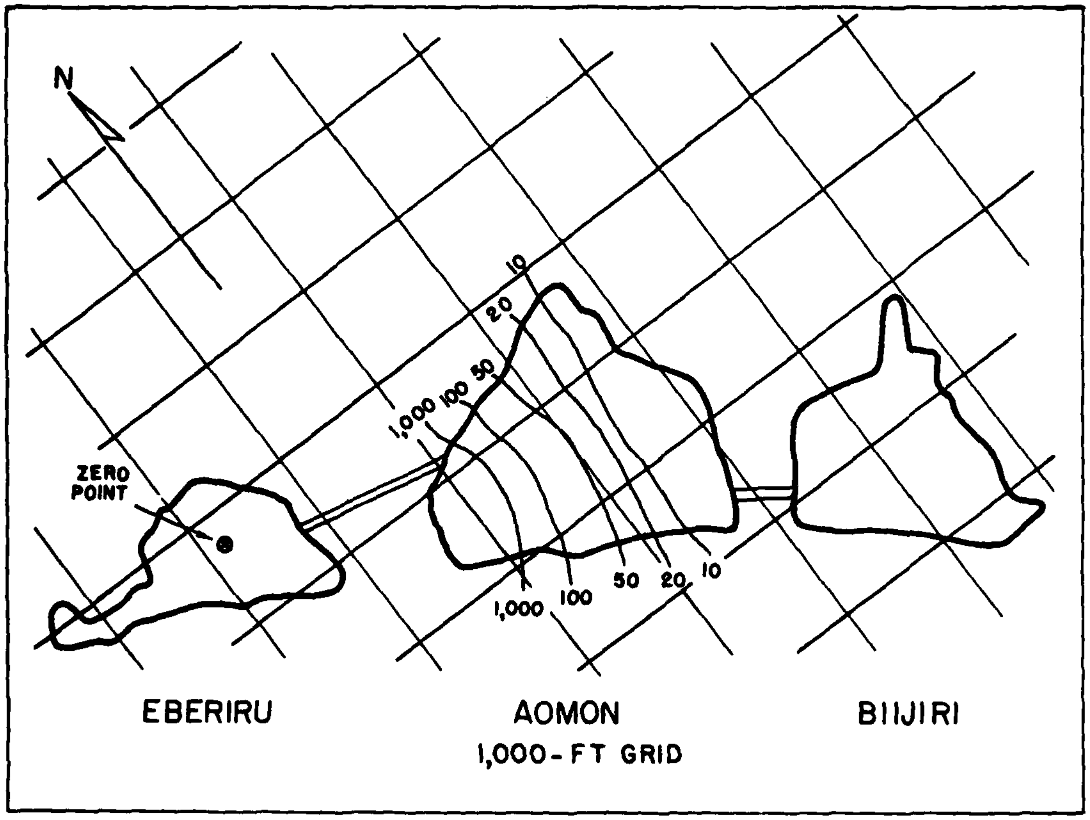

Fig. C.4 Aomon Survey, 14 May 1951, G+5. Intensities are mr/hr.

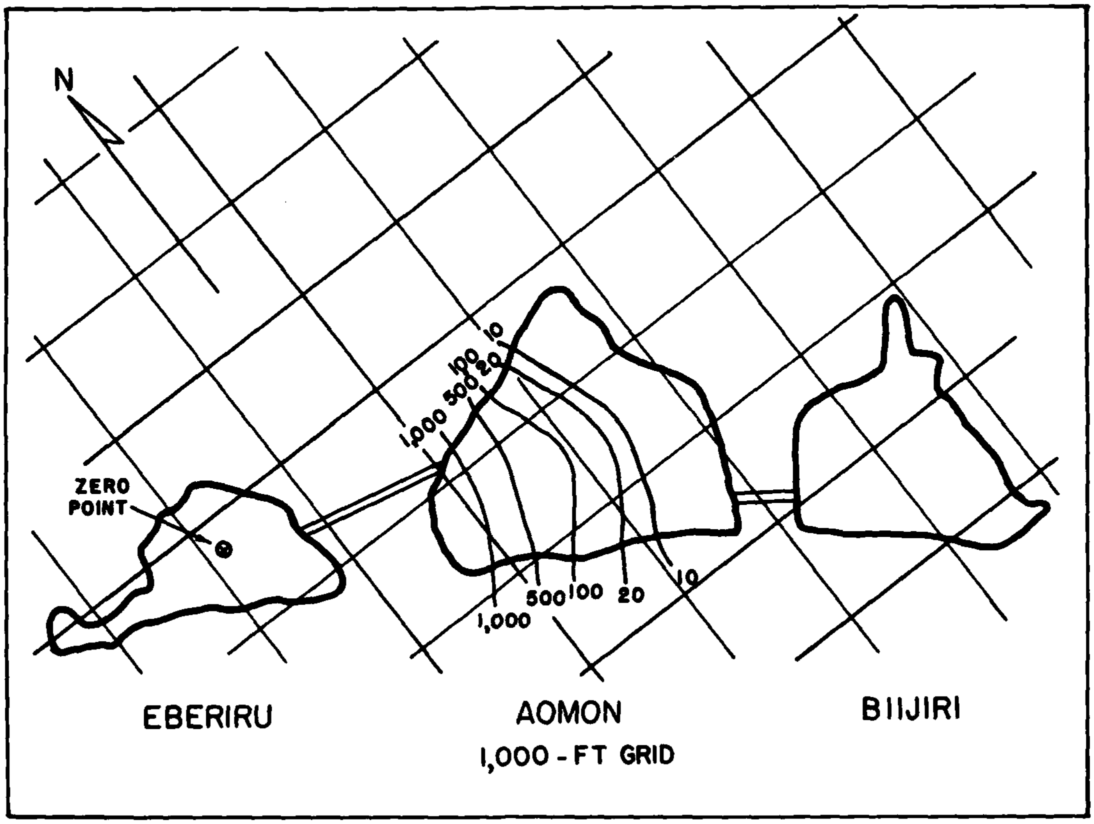

Fig. C.5 Aomon Survey, 18 May 1951, G+9. Intensities are mr/hr.

Appendix D

Shot Island Surveys, Item

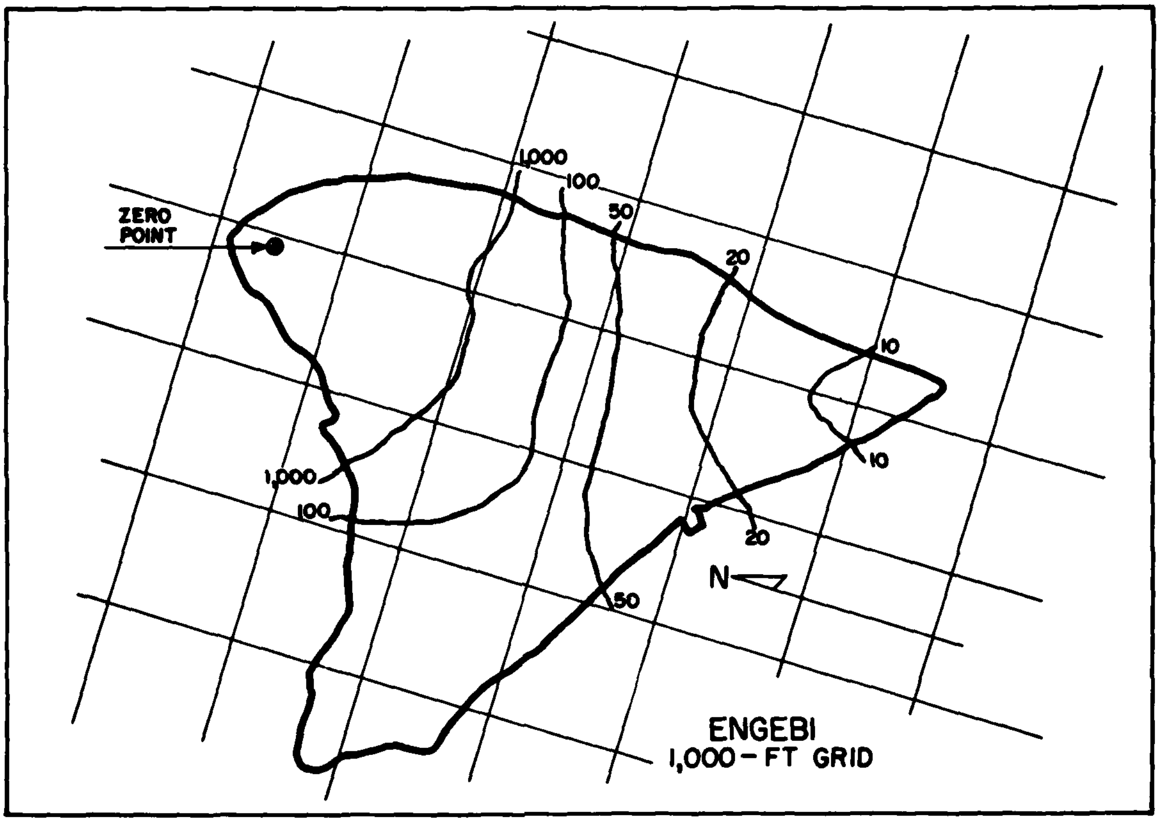

Fig. D.1 Engebi Survey, 26 May 1951, I+1. Intensities are mr/hr.

[redacted]

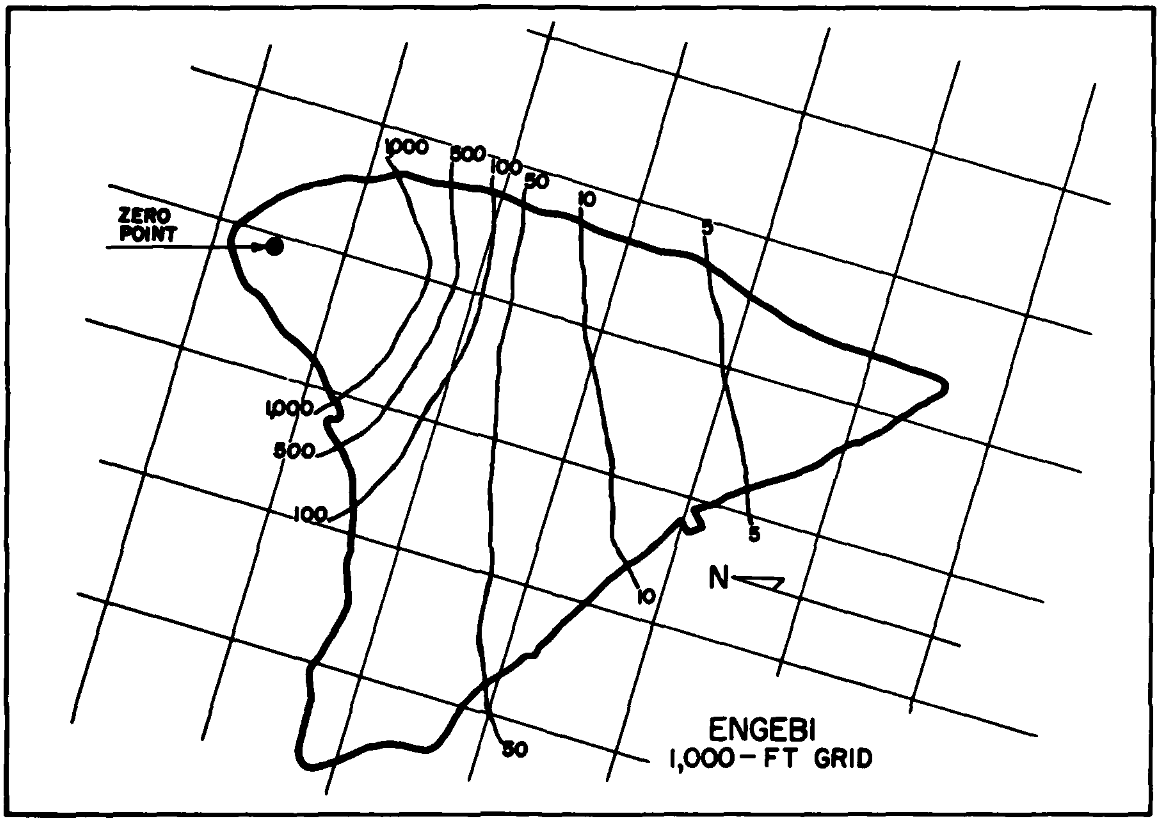

Fig. D.2 Engebi Survey, 28 May 1951, I+3. Intensities are mr/hr.

[redacted]

Appendix E

Major Items of Equipment

Analyzer, photographic, Weston, model 877	2
Alarm, pocket, radiation, experimental, model MX 7	28
Balance, analytical, w/keyboard and chain weights, type BCT	1
Cabinet, Kardex, 26 drawer	4
Chair, typist, adjustable back	1
Chamber, pocket, gamma, Victoreen, model 507	22
Chamber, pocket, gamma, Victoreen, model E-507, scale range 0–200 mr	3
Counter, portable, Geiger Mueller, type 263B, Victoreen	25
Charger-reader, chamber, pocket, gamma, Victoreen, model 392	5
Charger, dosimeter, Keleket	2
Counter, alpha flow, Radiation Counter Laboratories, internal sample, mark 12, model 1	3
Charger, dosimeter, Cambridge, model BM-17609	10
Charger, dosimeter, Beckman, model 103	7
Charger, dosimeter, model AV-2D	40
Charger, pocket	100
Charger, unit	2
Charger dosimeter, Keleket, model K-125	48
Counter, proportional, model 2111	1
Counter, Pee Wee	2
Cylinder, helium	1
Dosimeter, Keleket, 200 r	19
Dosimeter, pocket, Beckman, model 102	50
Dosimeter, pocket, 10 r, Keleket, model K-151 (AEC, model PIC-7B)	215
Dosimeter, pocket	11
Dosimeter, Keleket	27
Dosimeter, pocket, 10 r, Keleket, model K-151 (AEC, model PIC-7B)	202
Dosimeter, pocket, 50 r,	23
Dosimeter, pocket, 50 r, Keleket, model K-161 (AEC, model PIC-7C)	8
Dosimeter, 10 r, Keleket, model K-151	34
Dosimeter, pocket, Beckman, model 102, scale range 0–200 mr	40
Dosimeter, 50 r, Keleket, model K-161	100
Dosimeter, 200 mr, 50 r Keleket, model K-111A	101
Dosimeter, pocket, 50 r, Keleket, model K-161 (AEC, model PIC-7C)	32
Ejector, Willson, w/attachments in wooden case	1
Instrument panel, aircraft type	1
Light assembly, Ultraviolet, w/power supply	1
Meter, survey, alpha, AEC, model SIC-2A	10
Meter, survey, beta, El-Tronic, AEC, model SGM-18A	37
Meter, survey, beta-gamma, Victoreen, model 263B, w/headphones	50
Meter, survey, Victoreen, model 247E	40
Meter, survey, gamma, Victoreen, model 247 special (AEC, model SIC-9C)	10
Meter, survey, gamma, Victoreen, model 247A (AEC, model SIC-9V)	40
Meter, gamma monitor, Victoreen, AEC, model MIC-4A	25
Meter, volt-ohm, multirange, Radio City Products, model 664	3

Meter, Weston, model 772, type 6	4
Megohmmeter	2
Meter, Pee Wee, alpha (portable), model 41A	2
Meter, counting rate	2
Meter, survey, Victoreen model 263A	2
Meter, survey, gamma, Victoreen, model 747A	6
Meter, survey, beta-gamma, AEC, model SGM-18A	5
Meter, survey, ionization chamber	60
Microscope, Bausch & Lomb, research	1
Eyepiece, 12.5×	2
Objective, apochromat	3
Micrometer, filar eyepiece	1
Oscillograph, cathode ray, Du Mont, type 208B	1
Pump, Gast Mfg. Co., assembly, w/hose and one cascade impactor, in case	1
Pump, hand cranked, w/sample heads and straps, in carrying case	1
Recorder, Esterline-Angus, portable, DC milliammeter, scale range 0–5 ma, type 4, rapid feed, synchronized chain drive, 115 v, 60 cycle	3
Scaler, nuclear, model 163	3
Scaler unit, model 162	2
Scaler unit, model 161	1
Shield, lead, Radiation Counter Laboratories, vertical, mark 3, model 10	4
Stabilizer, voltage, Raytheon Mfg. Co., Cat. VR 3, 95–130 v input, 24 amp, 60 cycle, 1 phase, 115 v output, 120 watt	2
Set, test, insulation, portable	2
Tank, developing, stainless steel, w/pump	1
Test set, Leeds and Northrup, No. 5430	1
Tester, tube, Hickok, model 534B	1
Transformer, constant voltage, solar, Cat. No. 30809, primary 95–125 v, 1000 volt-amp, 60 cycle, 1 phase, secondary 115 v, 8.7 amp	1
Transformer, constant voltage, solar, Cat. No. 30808, primary 95–125 v, 500 volt-amp, 60 cycle, 1 phase, secondary 115 v, 4.35 amp	1
Tube, counter, Radiation Counter Laboratories, mark 1, model 70	20
Tube, counter, Radiation Counter Laboratories, mark 6, model 3	4
Unit, radiographic, portable, 110–220 v, 30 ma, 60 cycle AC, w/transformer, controls, tubes, cables, and accessories	1
Watch, stop	1
Water cooler, Filtrine, model PH 7	1